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Adamson, Sir K. T., 111, Collins Street, Melbourne, Victoria, Australia.
Ballard, Prof. C. F., Eastman Dental Hospital, Gray's Inn Road, W.C.1.
Campbell, Dr. J., 40, Ballater Drive, Bearsden, Glasgow, Scotland.
Clinch, Dr. L. M., 3, Fitzwilliam Place, Dublin, Eire.
Rix, R. E., Church Farm, High Laver, Ongar, Essex.
Selmer-Olsen, Prof. R., Ouro Ullern Terr 2, Oslo 3, Norway.
Townend, B. R., Cape Cottage, Uplands Road, Denmead, Portsmouth, Hampshire.

LIFE MEMBERS

Caseley, Miss R., 2, Hillside, Whitchurch, Nr. Pangbourne, Berkshire.
Downing, F. J., Carisbrooke, 238, London Road, Leicester, Leicestershire.
Endicott, C. L., 22, Harcourt House, 19, Cavendish Square, W.1.
Hayton-Williams, D. S., 3, Blaydon Close, Oxford, Oxfordshire.
Hovell, J. H., 92, Harley Street, W.1.
Hudson, J. A., Newlands, 13 Russell Road, Moor Park, Northwood, Middlesex.
Leatherman, G. H., 35, Devonshire Place, W.1.
Mayer, J. W., Stedham House, Surbiton Hill, Surbiton, Surrey.
Page, G. Scott, 65, Mount Ephraim, Tunbridge Wells, Kent.
Pilbeam, J. E., 46, Dornden Drive, Langton Green, Tunbridge Wells, Kent.
Still, Miss E. M., Hockett Cottage, Cookham Dean, Berkshire.
Taylor, A. G., 51, North End House, Fitzjames Avenue, W.14.
Taylor, A., Thornton, 175 Macquarie Street, Sydney, Australia.

ORDINARY MEMBERS

Adam, K. W., The White House, Belmont Street, Bognor Regis, Sussex.
Adams, C. P., Orthodontic Department, Royal Victoria Hospital, Belfast, Northern Ireland.
Adams, Miss S., 79, Harley Street, W.1.
Alder, Miss C. W., 'Westward', 259, Durham Road, Low Fell, Gateshead 9, Durham.
Alexander, J. M., The Gateway, Langport, Somerset.
Alexander, Mrs. S. H., 48, Bracken Hill, Burncross, Chapeltown, Sheffield, Yorkshire.
Allan, F., 64, Harley Street, W.1.
Allcorn, A. G. T., 7, Ocklynge Avenue, Eastbourne, Sussex.
Andrew, Miss E. M., 19, Hillcrest Road, Bramhall, Cheshire.
Angelman, J., 37, Upland Road, Eastbourne, Sussex.
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Arnheim, Miss E. E., 'Dunmore', 12, Hermon Hill, Wanstead, E.11.
Arnold, P. G., 18, Angus Close, Upper Willingdon, Eastbourne, Sussex.
Aron, B. D., 2, St. John Street, Manchester.
Ashton, J. R., 8, Lynnewood Place, Dundee, DD4 7HB, Angus.
Atherton, Dr. J. D., 17, Mentmore Road, Liverpool 18, Lancashire.
Attenborough, J. L., 52, Lucknow Drive, Mapperley Park, Nottingham, Nottinghamshire.
Audsley, C. W., Denbigh House, George Street, Ryde, Isle of Wight.
Bailey, J. C., 16, Castle Hill, Maidenhead, Berkshire.
Baker, A., 11, Church Crescent, Dumfries, Scotland.
Baldwin, Miss B. J., 31, Grove Road, Sutton, Surrey.
Bane, B., 322a, North End Road, S.W.6.
Barker, D., Droxford House, Charles Road, St. Leonards-on-Sea, Sussex.
Barnett, J. D. W., 11, Sylvan Avenue, Exeter, Devon.
Barrie, W. J. McK., The Dental Hospital, Park Place, Dundee, DD1 4HR, Scotland.
Bass, N. M., 4, Queen Ann Street, London, W1M 9LE.
Bass, T. P., 38, Canynge Square, Clifton, Bristol, BS8 3LB.
Beaton, A. G., 67, High Street, Aylesbury, Buckinghamshire.
Becker, A., 6, Howberry Road, Canons Park, Edgware, Middlesex.
Belcher, R. J., ' Hillview ', Enford, Pewsey, Wiltshire.
Bell, J. A., Springfield, Pangbourne Hill, Pangbourne, Berkshire.
Bell, R. S., 1, Portland Terrace, The Green, Richmond, Surrey.
Bennett, D. T., 'Escomb', Painshaw Field Road, Stockfield upon Tyne, Northumberland.
Bennett, J. C., 24D, Albermarle Road, Beckenham, Kent.
Bennett, T. G., 3, Barton Close, Harpenden, Hertfordshire.
Benzies, P. M., Orthodontic Clinic, The Dental School Hospital, Blundell Street, Leeds 1, Yorkshire.
Beresford, Dr. J. S., 21, Upper Wimpole Street, W.1.
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Berman, M., 57, Portland Place, W.1.
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Berry, Prof. D. C., The Dental Hospital, Lower Maudlin Street, Bristol 1.
Betteridge, Miss M. A., 114, Barnfield Wood Road, Beckenham, Kent.
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Bigg, Miss F. J., 12, Windfield Estate, Epsom Road, Leatherhead, Surrey.
Bird, Mrs. E., 388, Upper Richmond Road, S.W.15.
Bird, E. J. R., 25, Upper Wimpole Street, W.1.
Bird, R. G., St. Mary's Croft, Chapel Field North, Norwich, Norfolk.
Birkinhead, B., 84, Rodney Street, Liverpool 1, Lancashire.
Bligh, A. J., Durban, Crowborough Hill, Crowborough, Sussex.
Blyth, P. J., 6, Clifton Park, Clifton, Bristol, BS8 3BU, Gloucestershire.
Boa, J. T., 114a, High Street, Sutton, Surrey.
Bodenham, R. S., The Dental Hospital, St. Mary's Row, Birmingham 4, Warwickshire.
Bonnar, Miss E. M., 111, Osborne Park, Belfast 9, Northern Ireland.
Booth, Mrs. J. H., Pilgrim Cottage, 49, Oakridge Avenue, Radlett, Hertfordshire.
Booth, M. H., 67, Thorne Road, Doncaster, Yorkshire.
Bowden, D. E. J., 98, Grove Park, Knutsford, Cheshire.
Bradley, P. E., Cedar Hill, Littlebourne, Canterbury, Kent.
Bransby-Zachary, G. M., 103, Brighton Road, Sutton, Surrey.
Breach, Mrs. J. J., 27, Crescent Court, Park Hill, S.W.4.

Breakspear, E. K., 182, White Road, Quinton, Birmingham 32, Warwickshire.
Brearley, Mrs. H. E., 104, Clarence Gate Gardens, N.W.11.
Brenchley, M. L., Sweetfield House, Uplowman, Tiverton, Devonshire.
Brien, A. B., 88, Burdon Lane, Cheam, Surrey.
Briggs, C. P., 47, Arlington Avenue, Leamington Spa, Warwickshire.
Brigham, T. H., Manor Park House, Worksop, Nottinghamshire.
Broadway, E. S., 3, Thornely Drive, Ipswich, Suffolk.
Broadway, R. T., 'Tanglewood', Oliver's Battery Road, Winchester, Hampshire.
Brooke-Jones, Lt. Col. D. L., The Military Hospital, Catterick Camp, Yorkshire.
Brown, K. H., Cork Dental Hospital, John Redmond Street, Cork, Eire.
Brown, T. S., 22, Princes Avenue, Woodford Green, Essex.
Brown, W. A. B., Dental School, University of Wales, Heath, Cardiff, Glamorgan, Wales.
Buchan, A., 194, Ferry Road, Edinburgh 6, Scotland.
Buckley, L. A., Dental Department, Cork Dental Hospital, John Redmond Street, Cork, Eire.
Budd, G. F., 42, High Street, Tunbridge Wells, Kent.
Bull, C. C., The Gables, 8, Welholm Road, Grimsby, Lincolnshire.
Bulow, C. F. H., 20, Cedar Road, Sutton, Surrey.
Bunker, D. G., 17a, High Street, Biggleswade, Bedfordshire.
Burdekin, P. S., 25, Blossom Street, York, Yorkshire.
Burgess, P. T., Delgany, Esher Place Avenue, Esher, Surrey.
Burke, P. H., Addenbrookes Hospital, Hills Road, Cambridge, Cambridgeshire.
Burley, M. A., The Dental and Oral Surgery Dept., South Devon and East Cornwall Hospital, Greenbank Road, Plymouth, Devon.
Burnapp, D. R., 'Arcadia', Outwood Lane, Chipstead, Surrey.
Burston, Dr. W. R., 27, Howbeck Road, Oxten, Birkenhead, Cheshire.
Bush, P. G., 40, Bertram Drive, Meols, Wirral, Cheshire.
Butler, F. H., 9a, Hill Avenue, Amersham, Buckinghamshire.
Campbell, A. Courtney, 75, Lichfield Street, Hanley, Stoke-on-Trent, Staffordshire.
Campbell, Alan C., 40, Harley Street, W.1.
Campbell, R. A., c/o Regional Dental Office, Ministry of Health, 41, Tothill Street, S.W.1.
Campbell-Wilson, Miss M., 352, Duffield Road, Derby, Derbyshire, DE3 1ER.
Campion, P. C. S., 61, Wimpole Street, W.1.
Carr, A. S., Longford House, 9, Sidney Road, Staines, Middlesex.
Carvalho, Mrs. E. M., 3, Springfield Road, N.W.8.
Catchside, J., 2, Queen's Parade, Bath, Somerset.
Challis, L. C., 8, Cromford Way, New Malden, Surrey.
Chamberlain, G. H., 434, Narborough Road, Leicester.
Chapman, A. S., Coniston, 22, Old Woking Road, West Byfleet, Surrey.
Chapman, Mrs. P. A., Lynton Grove, Bragden Lane, Barnoldswich, Via Colne, Lancashire.
Chmielewski, J. K., 165, Pitshanger Lane, W.5.
Christian, G. C., 6, Dartford Road, Sevenoaks, Kent.
Christie, B. F., 99, St. Andrew's Drive, Bridge of Weir, Renfrewshire, Scotland.
Christy, D. F., 4, Scotland Bridge Road, New Haw, Weybridge, Surrey.
Clark, W. J., Lundin Lea, Leven Road, Lundin Links, Fife, Scotland.
Clarke, N. F., 152, Harley Street, W1N IHH.
Clifford, E. J. S., 84, Rodney Street, Liverpool 1, Lancashire.
Clough, E. O., 54, Hadleigh Road, Leigh-on-Sea, Essex.
Clow, I. M., 35, Manswood Road, Glasgow, S.3.
Cobb, R. J. MacDonald, c/o 57, The Avenue, Norwich, Norfolk NOR 27G.
Cockburn, A., The Dental Hospital, 211, Renfrew Street, Glasgow C.3, Scotland.
Coker, F. L., Keay House, Town Square, Basildon, Essex.
Collin, B. D., 46, Vaughan Lodge, Fair Acres, Hayesford Park, Bromley, Kent.
Collins, R. A., Farthings, 51, Babylon Way, Ratlon, Eastbourne, Sussex.
Combes, T. J., 9, Beechlands, Bishop's Stortford, Hertfordshire.
Connolly-Meagher, T. A., 42, Cop Lane, Penwortham, Preston, PR1 0SR.
Cook, J. T., Orthodontic Department, General Hospital, Ayresome Green Lane, Middlesbrough, Yorkshire.
Cookson, A. M., Orthodontic Department, Good Hope General Hospital, Sutton Coldfield, Warwickshire.
Coote, J. D., Middlesbrough General Hospital, Ayresome Green Lane, Middlesbrough, Teesside, Yorkshire.
Corfe, R. J. H., Combe Hill House, Whiston, Northamptonshire.
Cousins, A. J. P., 80, Cathedral Road, Cardiff, Glamorgan, Wales.
Coyle, Miss N. M., 141, Epsom Road, Guildford, Surrey.
Coyle, P. R. W., 24, Forde Park, Newton Abbot, Devon.
Crawford, J. F., 73, Lancaster Road, St. Albans, Hertfordshire.
Crooks, J. D., 60, The Hall, Foxes Dale, Blackheath, S.E.3.
Crossman, I. G., 24, Weald Rise, Haywards Heath, Sussex.
Crowther-Kemp, Mrs. J. M., 7, Freeland House, Silverdale Road, Eastbourne, Sussex.
Cruickshank, A. J., 48, King Street, Manchester 2, Lancashire.
Cryer, B. S., 13, Willow Dene, Bushey Heath, Herts.
Cullingford, J. T. Powell, 14, West Terrace, Eastbourne, Sussex.
Dagger, T., Parabola House, Cheltenham, Gloucestershire.
Dallas, H. A., 5, Kensington Park, Bangor, Co. Down, Northern Ireland.
Davidson, I. F., Orthodontic Department, Dental Unit, Royal South Hants Hospital, Southampton, Hampshire.
Davies, A. H. P., 18, Porth-y-Castell, Barry, Glamorgan, Wales.
Davis, Mrs. M. E. H., 3, Ascot Road, Moseley, Birmingham 13, Warwickshire.
Day, A. J. W., 17, Portland Road, Edgbaston, Birmingham 15, Warwickshire.
Di Biase, D. D., 42, Hornbeam Road, Theydon Bois, Essex.
Dickson, G. C., Orthodontic Department, Royal Portsmouth Hospital, Portsmouth, Hampshire.
Dickson, W. L., 302, Broadwater Crescent, Stevenage, Hertfordshire.
Dimock, J. R., Redlingtons, Silver Street, Enfield, Middlesex.
Dixon, D. A., 6, Nicholas Avenue, Whitburn, Sunderland, Co. Durham.
Dockrell, Dr. R. B., Dublin Dental Hospital, Lincoln Place, Dublin 2, Eire.
Dodd, Miss J. M., Byways, Westfield Road, Bishop's Stortford, Hertfordshire.
Dods, M. H., 218, West Wycombe Road, High Wycombe, Buckinghamshire.
Down, G. R., 58, Peppercombe Road, Eastbourne, Sussex.
Downing, M. J., 238, London Road, Leicester, Leicestershire.
Dowsett, J. R., 5, Lullarook Close, Norheads Lane, Biggin Hill, Kent.
Dumbrell, Miss J. M., Greenlands, Sheringham, Norfolk.
Eagland, M. C., 21, Billing Road, Northampton, Northamptonshire, NN1 5AW.
Eales, Miss E. A., 19, Kilfield Road, Bishopstown, Swansea, Glamorgan.
Edmonds, W. H., Buckingham House, Graham Road, Great Malvern, Worcestershire.
Edworthy, S. W., 13, Mount Street, Battle, Sussex.

Eirew, H. L., 2, Palatine Road, Withington, Manchester, M20 9JH.
Ellis, D. S., 83a, High Street, Gillingham, Kent.
Ellisdon, P. S., 27, Osgood Avenue, Orpington, Kent.
Emery, B. J., Glencairn, 73, Orton Lane, Wombourne, Wolverhampton, Staffordshire.
Endacott, D. J., 12, Alexandra Road, Mutley, Plymouth, Devon.
England, Mrs. M., 7, Abbey Close, Abingdon, Berkshire.
Erskine, R. B., Department of Orthodontics, School of Dental Surgery, 31, Chambers Street, Edinburgh 1, Scotland.
Evans, W. D. P., Dental Clinic, Health Department, Swyddfa'r Sir, Aberystwyth, Wales.
Everard, G. D., Church House, Frampton-on-Severn, Gloucestershire.
Farrant, Miss S. D., 39, Rutland Gate, S.W.7.
Finn, S. D., 21, Lower Baggot St., Dublin 2, Eire.
Fitzgerald, G. M., 28, Merrion Square, Dublin, Eire.
Fletcher, G. G. T., Orthodontic Department, Eastman Dental Hospital, Gray's Inn Road, W.C.1.
Flood, N., 51, Leeson Park, Dublin 6, Eire.
Foster, E. S., Two Corners, Sudbrooke, Lincoln, Lincolnshire.
Foster, Prof. T. D., Orthodontic Department, The Dental Hospital, St. Mary's Row, Birmingham 4, Warwickshire.
Foxton, D., 15a, Commercial Street, Hereford, Herefordshire.
Frankland, W., 88, Mansfield Road, Nottingham, Nottinghamshire.
Franklin, Mrs. J. A., 109a, Hare Lane, Claygate, Esher, Surrey.
Franks, Miss F. L., c/o Barclays Bank, 36, Milsom Street, Bath, Somerset.
Fraser, A., 21, Newland Road, Banbury, Oxfordshire.
Frazer, D., 230, Dobcroft Road, Sheffield, SL1 9LJ.
Frazer, Mrs. J., 5, Pendragon, Lister Lane, Bradford 2, Yorkshire.
Frazer, M. L., 7, The Green, Twickenham, Middlesex.
Freeman, H. D., 22, Seymour Street, Portman Square, W.1.
French, J. H., 6, Silver Street, Southsea, Portsmouth, Hampshire.
Friend, Mrs. D. J., The Old Rectory, Lichfield Road, Stone, Staffordshire.
Frischmann, I., 33, Carden Avenue, Brighton, BNI 8NA.
Fulstow, E. D., 2, Forge End, Alwalton, Peterborough, Huntingdon, PE7 3UT.
Furness, M. J., 3, Ingleby Way, Wallington, Surrey.
Gardiner, J. H., Orthodontic Department, Charles Clifford Dental Hospital, Wellesley Road, Sheffield 10 Yorkshire.
Gibson, A. C. L., Edinburgh Dental Hospital, 31, Chamber Street, Edinburgh, Scotland.
Glass, D. F., 4, Elwick Road, Ashford, Kent.
Glover, E. A., Rectory House, 40, Epsom Road, Guildford, Surrey.
Godfrey, O. Harcourt, Croft House, Bourne Hill, Salisbury, Wiltshire.
Godfrey, W. G., Buckingham House, Graham Road, Great Malvern, Worcestershire.
Golden, A., 16, Dunstan Road, N.W.11.
Goodman, P. E., 59, Fairfield Road, Epping, Essex.
Gould, D. G., 4, Wellington Circus, Nottingham, NG1 5AL.
Gould, M. S. E., Eastman Dental Hospital, Gray's Inn Road, W.C.1.
Gravely, J. F., Dental School and Hospital, The University, Leeds 1, Yorkshire.
Greene, E., 21, Lower Baggot Street, Dublin 2, Eire.
Greenfield, D. G., Millbush Farm, East Orchard, Shaftesbury, Dorset.
Greenwood, A. B., 5, Peter's Place, Brighton, Sussex.
Greenwood, A. W., 458, Newark Road, Lincoln, Lincolnshire.
Greig, W. B. W., 100, Harley Street, W.1.
Grice, A. R., Pinewood House, Muster Green, Haywards Heath, Sussex.
Griffith, H. G., 16, College Road, Eastbourne, Sussex
Griffiths, P. J. T., 19, East Hill, Colchester, Essex.
Grossmann, W., 79, Harley Street, W.1.
Grundy, Mrs. M., The Dental Hospital, St. Mary's Row, Birmingham 4, Warwickshire.
Halden, J. R., Flat 9, 103, Harley Street, W.1.
Hall, J. J., Flamstone House, Bishopstone, Salisbury, Wiltshire.
Hallett, Prof. G. E. M., 63, Runnymede Road, Darras Hall, Ponteland, Newcastle upon Tyne, Northumberland.
Halliday, Dr. R. W., 2, The Grove, Woking, Surrey.
Hardingham, A. J., Charlton House, Cirencester, Gloucestershire.
Hardman, Mrs. F. A., 53, Berylands Road, Surbiton, Surrey.
Hartley, D. T., Turner Dental School, Bridgeford Street, Manchester 15, Lancashire.
Harvey, Miss J. C., Orthodontic Department, Addenbrookes Hospital, Hills Road, Cambridge, Cambridgeshire.
Harvey, P. D., 22, Norham Gardens, Oxford, Oxfordshire.
Hathaway, R., 81, Chapel Street, Billericay, Essex.
Haynes, S., 2a, Strathearn Place, Edinburgh 9, Scotland.
Heffer, P. T., 22, Russell Mansions, 144, Southampton Row, W.C.1.
Hegarty, Prof. M., Department of Orthodontics, Cork Dental Hospital, John Redmond Street, Cork, Eire.
Henry, C. Bowdler, 62, Harley Street, W.1.
Henry, T. Cradock, 8, Upper Wimpole Street, W.1.
Hewitt, A. B., 5, Priors Road, Hemingford Grey, Huntingdon.
Hill, N. L., 69, Northampton Road, Addiscombe, Croydon, Surrey.
Hilton, R., 293, Windsor Road, Oldham, Lancashire.
Hobson, G. S., 10, Elmwood Avenue, Belfast, Northern Ireland.
Holmes, B., Scartho Road Hospital, Grimsby, Lincolnshire.
Holmes, G. F., Wheatcroft, Maldon Road, Eves Corner, Danbury, Essex.
Hooper, J. D., Orthodontic Department, Royal Victoria Hospital, Boscombe, Bournemouth, Hampshire.
Hope, H. D. A., The Briars, St. John's Road, Newbury, Berkshire.
Hopkin, Dr. G. B., 67, Cluny Gardens, Edinburgh 10, Scotland.
Hopper, J., 7, Grosvenor Avenue, West Kirby, Wirral, Cheshire.
Horswill, P. N., Avon House, Amesbury, Wiltshire.
Horton, J. J., Dene End, Deneside, Eastdean, Eastbourne, Sussex.
Houston, J. G., 42, Helensburgh Drive, Glasgow, W.3, Scotland.
Houston, W. J. B., 71, Craddocks Avenue, Ashstead, Surrey.
Howard, R. D., Dental Department, King's College Hospital, S.E.5.
Huddart, A. G., Lyndale, 11, Dippons Drive, Tettenhall Wood, Wolverhampton.
Huggins, D. G., Parkfield, Warrington Road, Hoole, Chester, Cheshire.
Hughes, F. J., 3, Windsor Crescent, Elderslie, Johnstone, Renfrewshire, Scotland.
Hughes, J. P., 135, Dawson Road, Hyde, Cheshire.
Hunter, F. W., 4, Cavan Road, Redbourn, Hertfordshire.
Hutchinson, D., 61, Plantation Gardens, Wigton Lane, Leeds, 17, Yorkshire.
Hutchinson, G. T., 34a, Hans Road, S.W.3.
Hutton, J. L., 2, Springfield Road, King's Heath, Birmingham 14, Warwickshire.
Irwin, L. M., 29, High Street, Sandwich, Kent.
Isaacson, K. G., 6, Oak End Close, Southborough, Tunbridge Wells, Kent.
Iyer, V. S., The Dental Hospital, Bridgeford Street, Manchester 15, Lancashire.
Jackson, D., Leeds University Dental School, Blundell Street, Leeds 1, Yorkshire.

Jackson, Mrs. S. R., Hawthorne House, 18, Chapel Lane, Wilmslow, Cheshire.
Jameson, G. D., 12, Southend Avenue, Darlington, Co. Durham.
Jefferys, Dr. J. F., 7a, Queen Victoria Road, High Wycombe, Buckinghamshire.
Jepson, P. D., 30, High Street, Ipswich, Suffolk, IP1 3QL.
Johnson, D. B., Orthodontic Department, (St. James's) University Hospital, Leeds, Yorkshire, LS9 7TF.
Johnson, F. K., Bank House, White Friars, Chester, Cheshire.
Johnson, J. S., Orthodontic Unit, Booth Hall, Children's Hospital, Charlestown Road, Blackley, Manchester 9.
Johnson, S., Flat 1, 24, Pembridge Square, W.2.
Jones, W. B., 62, Buryfield Road, Solihull, Warwickshire.
Kaplan, R. G., c/o London House, Mecklenburgh Square, W.C.1.
Keiller, A. B., 23, St. Georges Road, Cheltenham, Gloucestershire.
Keith, J. E., 13, Upper Fitzwilliam Street, Dublin, Eire.
Keniry, A. J., 'Hilbre', Chappel Road, Great Tey, Essex.
Kennedy, G. F., 126, Merion Road, Ballsbridge, Dublin 4, Eire.
Kerr, G. A., 47, Beaumont Street, W.1.
Kerr, Miss M. R., 4, Marlborough Court, Marlborough Hill, Harrow, Middlesex.
Kettle, M. A., 35, Harley Street, W.1.
Kettle, R. G., 43, High Street, Wimbledon Common, S.W.19.
Kettler, C. J. R., 21, Rothsay Road, Bedford, Bedfordshire.
Knowles, C. C., Oak Lodge, Windmill Lane, Appleton, Cheshire.
Kolb, T. T., 49, Dyer Street, Cirencester, Gloucestershire.
Kürer, J., 39, Deansgate, Manchester 3, Lancashire.
Langford, L. F., 12, Standisgate, Wigan, Lancashire.
Lawrie, D. A., 1, North Guildry Street, Elgin, Moray, Scotland.
Lawton, D. B., ' London House ', 135, London Road, Sevenoaks, Kent.
Laxton, Mrs. L., 3, East Hill, Colchester, Essex.
Leech, H. L., Greensleeves, Weedon Lane, Amersham, Buckinghamshire.
Leighton, Prof. B. C., Dental School, King's College Hospital, S.E.5.
Lennox, A. A., 298, Cuiken Terrace, Penicuik, Midlothian, Scotland.
Lentin, S. A., 99, Edgeley Road, Edgeley, Stockport, Lancashire.
Lester, H., 70, Sackville Road, Hove, Sussex, BN3 3HA.
Levason, J. A., 137, Chatsworth Road, Brondesbury, N.W.2.
Levison, H., 16, High Park, Stafford, Staffordshire.
Lewis, A. S., 187, Cathedral Road, Cardiff, Glamorgan, Wales.
Lewis, E. E., Blandy House, Hart Street, Henley-on-Thames, Oxfordshire.
Lewis, G. A., 17, Maytree Road, Chandler's Ford, Hampshire.
Lewis, H. G., Orthodontic Department, University of Wales, Dental School, Heath, Cardiff, Glamorgan, Wales.
Lindon, Mrs. E. G., 43, The Avenue, St. Margaret's-on-Thames, Middlesex.
Littlefield, W. H., The Dental Hospital, College Street, Newcastle upon Tyne, Northumberland.
Logan, W. Russell, 8, Chester Street, Edinburgh 3, Scotland.
Lovius, B. B. J., The Dental Hospital, Pembroke Place, Liverpool 3, Lancashire.
Lowenberg, Mrs. B. F., 40, Howard Walk, N.2.
Luffingham, J. K., 6, Milton Hill, Milton, Dumbarton, Scotland.
Lynch, Miss E. M., 146, Holland Park Avenue, W.11.
McBride, L. J., 66, Rowcliffe Avenue, Chester, Cheshire.
McCall, Miss M. C., 12, Swain's Lane, Highgate, N.6.
McCallin S. Granger, 53, Portland Place, W.1.
MacCallum, W. A., 14, Royal Terrace, Glasgow C.3, Scotland.
McCartney, T. I., 172, Upper Newtownards Road, Belfast 4, Northern Ireland.
McCartney, T. P. G., c/o Dental Clinic, Red Hill Street, Wolverhampton, WV1 1NR.
MacCauley, F. J. L., Birmingham Dental Hospital, St. Mary's Row, Birmingham 4, Warwickshire.
McCormack, M. E., 'Cruachan', 31, Tailyour Crescent, Montrose, Angus, Scotland.
McCracken, J. G., Dental Department, Lancaster Royal Infirmary, Lancaster, Lancashire.
McDonald, A. A. M., 5, Baillieswells Terrace, Bieldside, Aberdeen, Scotland.
McDonogh, P. F., 'The Sheiling', 14, Woodcote Park Avenue, Purley, Surrey.
McEwen, Prof. J. D., Orthodontic Department, The Dental Hospital, Park Place, Dundee, Scotland.
McGonigal, F., 5, Snowdon Place, Stirling, Fifeshire, Scotland.
MacInerney, Miss J., 85, Brook Green, W.6.
McKane, N. B., 57, Friar Gate, Derby, Derbyshire.
McKechnie, R., 5, Stanley Avenue, Paisley, Scotland.
Mackenzie, Miss M. P., Flat 1, 38, Murray Road, Northwood, Middlesex.
Malik, Miss R., 24, Ellerdale Road, N.W.3.
Manning, Mrs. J. D., 'Claysands', Pelhams Walk, Esher, Surrey.
Marsh, W., 6, Grove Place, Lymington, Hampshire.
Marston, R. W., 30, Loughborough Road, West Bridgeford, Nottinghamshire.
Martin, D. W., 27, Hartfield Road, Eastbourne, Sussex.
Martin, H. C., 2A, Chingford Lane, Woodford Green, Essex.
Martin, J. H., 25, South Oswald Road, Edinburgh 9, Scotland.
Marx, R., 42, Hempstead Road, Watford, Hertfordshire.
Mason, Mrs. E. M. B., Rhu-na-Dee, Cults, Aberdeen, Scotland. AB1 9NA.
Mason, Mrs. L. G., 27, Newhouse Road, Bovingdon, Hertfordshire.
Maudsley, Mrs. B. A., Heathend House, Windsor Road, Ascot, Berkshire.
Mears, Miss R., 37, David Street, Kirkcaldy, Fifeshire, Scotland.
Menezes, D. M., Dental School, St. Mary's Row, Birmingham 4, Warwickshire.
Metcalf, J., The Beeches, Pound Lane, Knockholt, Nr. Sevenoaks, Kent.
Mew, J. R. C., Hill House, Clarnicarde Road, Tunbridge Wells, Kent.
Miall, T. J., 5, Braidwood Terrace, North Hill, Plymouth, Devon.
Miller, Miss M. N., Dental Clinic, Sighthill Health Centre, Calder Road, Edinburgh 11, Scotland.
Miller, Mrs. P. S., 47, Gatley Road, Cheadle, Cheshire.
Mills, Dr. J. R. E., Orthodontic Department, Eastman Dental Hospital, Gray's Inn Road, W.C.1.
Minors, C. J., 9, Southbourne Road, Sheffield, Yorkshire.
Mole, D. O., ' The Gables ', 9, St. James's Road, Dudley, Worcestershire.
Morris, V. B., Dublin Dental Hospital, Lincoln Place, Dublin 2, Eire.
Morse, P. H., 24, Upper Third Avenue, Frinton-on-Sea, Essex.
Moss, J. P., 8, Langdon Drive, N.W.9.
Muir, J. D., Dental Department, City General Hospital, Stoke-on-Trent, Staffordshire.
Munday, M. J., 161, Turners Hill, Cheshunt, Hertfordshire.
Munns, D., 45, St. Andrews Road, Malvern, Worcestershire.
Munro, D., The Dental Hospital, Park Place, Dundee, Scotland.
Murgatroyd, M. J., Fern Lea, Church Road, Mellor, Nr. Stockport, Cheshire.
Murray, Miss J. P., 16, Handley Court, Riversdale Road, Aigburth, Liverpool 19, Lancashire.

Nagasinghe, Miss L., 4, Courtfield Gardens, S.W.5.
Nagpaul, R. K., Alder Hey Children's Hospital, Eason Road, West Derby, Liverpool 12, Lancashire.
Nelson, J., 40, Epsom Road, Guildford, Surrey.
Nesbitt, A., 19, Selwyn Road, Eastbourne, Sussex.
Newbury, A. C., 21, Randolph Crescent, Maida Vale, W.9.
Newell, Major M. J., c/o Westminster Bank Ltd., Park Row, Leeds 1, Yorkshire.
Nicol, W. A., The Dental Hospital, Lower Maudlin Street, Bristol 1, Gloucestershire.
Nicolls, J., 6, Boxgrove Road, Guildford, Surrey.
Niven, W. N. McL., c/o Ministry of Health, 41, Tothill Street, S.W.1.
Noar, G. A., 'Carisbrook', Knowsley Road, Whitefield, Manchester, Lancashire.
Norris, N., 'Balan Farm', Packhorse Lane, Wythall (Kings Norton), near Birmingham, Warwickshire.
O'Brien, J. D., 27, St. Mary's Road, Market Harborough, Leicester, Leicestershire.
O'Connor, P. J., 1, Sidney Place, Cork, Eire.
Ogston, R. D., Maple Lea, Hindhead, Surrey.
Orme-Smith, D., Lion Hill, Tadworth Street, Tadworth, Surrey.
Orton, H. S., Old Elms, 12, Walpole Road, Surbiton, Surrey.
Ovington, Major H. M. T. Y., Army Dental Centre, Borgoyne Barracks, Shorncliffe, Kent.
Page, J., 12, Oak End Close, Southborough, Tunbridge Wells, Kent.
Panter, Miss A. 35, St. Albans Road, N.W.5.
Parker, C. D., 11, Carisbrooke Avenue, South Knighton, Leicester, Leicestershire.
Parkhouse, R. C., 44, Lychgate Avenue, Pedmore, Stourbridge, Worcestershire.
Parr, P. T., Carlton Court, Carlton Drive, S.W.15.
Parry, H. L., 36, Uplands Crescent, Uplands Square, Swansea, Wales.
Patel, V. J., 57, Back Chesterfield Road, Sheffield 8, Yorkshire.
Peace, Mrs. H. C., 15, Southmead Road, Westbury-on-Trym, Bristol, Gloucestershire.
Pearsall, M. L. H., 8, Springfield Park Road, Horsham, Sussex.
Perks, E. J., Angle House, St. Austell, Cornwall.
Pettman, J. R., 107, Northampton Road, Kettering, Northamptonshire.
Phelan, M. R. 22, Douglas Road, Harpenden, Hertfordshire.
Plint, D. A., Hospital for Sick Children, Great Ormond Street, W.C.1.
Pogrel, H., Grayton, County Road North, Ormskirk, Lancashire.
Pook, R. S., 19, Wimpole Street, W.1.
Potokar, S. L., 23, Bramble Drive, Sneyd Park, Bristol 9, Gloucestershire.
Potts, Miss A., 8, Mill Rise, Northallerton, Yorkshire.
Poulter, N. M., Garth, 108, Staplegrove Road, Taunton, Somerset.
Powell, J. E., 20, Chorley New Road, Bolton, Lancashire.
Powell, S. J., 7, Savona Court, The Downs, Wimbledon, S.W.20.
Price, A. H. K., Orthodontic Department, Charles Clifford Dental Hospital, Wellesley Road, Sheffield 10, Yorkshire.
Pringle, K. E., Dental Department for Children, Guy's Hospital, S.E.1.
Ratcliffe, C., 120, Green Lane, Bolton, Lancs.
Rayne, J., Wexham Park Hospital, Slough, Buckinghamshire.
Read, Mrs. L. R., 19, Rydons Lane, Old Coulsdon, Surrey.
Reed, R. T., Dental Department for Children, Guy's Hospital, S.E.1.
Reid, D., Sandringham, Guildford Road, Woking, Surrey.
Reynolds, B. F., Hampton House, 176, London Road, Leicester, Leicestershire.
Reynolds, I. A., Wentworth, Newport, Pembrokeshire.
Rhodes, A. A., 4, Palatine Road, Withington, Manchester, Lancashire. M20 9JH.
Rice, V. G., Woodbourne, Knoll Road, Camberley, Surrey.
Rich, B. C., Longdene Lodge, Haslemere, Surrey.
Richards, H., 85, Harley Street, W.1.
Richardson, A., 33, Cherryvalley Park, Belfast 5, Northern Ireland.
Richardson, Mrs. M. E., 33, Cherryvalley Park, Belfast 5, Northern Ireland.
Ridley, Miss D. R., Orthodontic Department, Raigmore Hospital, Inverness, Scotland.
Ritchie, Miss J., 19, Harcourt House, 19, Cavendish Square, WIM 9AB
Ritchie, J. C., 14, South Street, Romford, Essex.
Roberts, D. A. H., Joyce Green Hospital, Dartford, Kent.
Roberts, E. T. E., Elmhurst, Garth Road, Bangor, N. Wales.
Roberts, G. H., Royal Aberdeen Children's Hospital, Westburn Drive, Aberdeen, Scotland. AB9 2ZG.
Roberts, Mrs. S., 11, Farthings Close, Eastcote, Pinner, Middlesex.
Robertson, Prof. N. R. E., The Dental School, University of Wales, Heath, Cardiff, Glamorgan, Wales.
Robertson-Ritchie, D., Market House, Market Avenue, Chichester, Sussex.
Robertson-Ritchie, Mrs. E. L., Market House, Market Avenue, Chichester, Sussex.
Robson, P. S., 116A, Hill Lane, Southampton, Hampshire.
Rodesano, A. J., Macavity, Sheephouse Road, Maidenhead, Berkshire.
Rogers, D. A., 46, Ickenham Road, Ruislip, Middlesex.
Rose, J. S., 30, Wimpole Street, W.1.
Rose, R. J., 22, Grenville Gardens, Birchington, Kent.
Rule, D. C., Holly House, Camden Park, Tunbridge Wells, Kent.
Rumble, J. D., 19, East Cliff, Dover, Kent.
Russell, L. H., 378, Finchley Road, Hampstead, N.W.3.
Rydemark, J. E., 110, Harley Street, W.1.
Safinia, K., 90, Cornwall Gardens, S.W.7.
Salter, R. C. P., 149, Kings Road, Westcliff-on-Sea, Essex.
Sarll, D. W., 3 Sorlus Close, Unwin Street, Salford 6, Lancashire.
Savage, M., 31, Beaumont Street, Oxford, Oxfordshire.
Schachter, H., 115, Harley Street, W.1.
Scheer, B., 66, Corningham Road, N.W.11.
Schuler, L. H., 28, Devonshire Place, W.1.
Sclare, Miss R., 5, Sandhill Drive, Alwoodley, Leeds, Yorkshire.
Scoones, J. M., 110, St. John's Road, Tunbridge Wells, Kent.
Scott, M. F., 5, The Armoury, London Road, Shrewsbury, Shropshire.
Scott, Miss M. K., 73, Home Park Road, Wimbledon, S.W.19.
Scutt, Miss E. M., 6, The Avenue, West Wickham, Kent.
Seel, D., Orthodontic Department, University Hospital of Wales, Dental Hospital, Heath, Cardiff, Glamorgan, Wales.
Selwyn-Barnett, B. J., 76, Northiam, Woodside Park, N.12.
Senior, W. B., 2, St. John Street, Manchester 3, Lancashire.
Sexton, Mrs. A., Cornel Court, Foxbrook, Dublin, Eire.
Seymour, A. J. H., 16, Creffield Road, Colchester, Essex.
Shapland, A. F. D., Burnside, 384, Topsham Road, Countess Weir, Exeter, Devon.
Sharland, R. J., 30, Wimpole Street, W.1.
Shenton, F. C., Orthodontic Department, Royal Alexandra Hospital, Dyke Road, Brighton 1, Sussex.
Shotts, A., 3, Scotch Common, West Ealing, W.13.
Shuff, R. Y., 5, Woodland Place, Totley Rise, Sheffield, Yorkshire.
Sider, Mrs. V., 48, Aylestone Avenue, Brondeslay Park, N.W.6.
Silver, M. M., 27, St. John's Grove, N.19.
Sissons, H. P., 122, Walter Road, Cardiff, Glamorgan, Wales.

Sissons, K., 58, Thornstree Drive, West Monkseaton, Whitley Bay, Northumberland.
Smart, Major R. A., British Military Hospital, Rinteln, B.F.P.O. 29.
Smith, B. D., 56, Harley House, Marylebone Road, W.1.
Smith, D. I., 56, Harley House, Marylebone Road, W.1.
Smith, K. A., 23, Fosse Road Central, Leicester.
Smith, T., Carisbrooke, 238, London Road, Leicester.
Softley, J. W., Orthodontic Department, The Churchill Hospital, Headington, Oxford, Oxfordshire.
Soul, D. F., 62, Station Road, Chingford, E.4.
Spencer, J. S., 12, Clarendon Gardens, Tunbridge Wells, Kent.
Standing, R. A., 24, Bore Street, Lichfield, Staffordshire.
Steel, G. H., 70, The Rise, Darras Hall, Ponteland, Northumberland.
Stephens, C. D., 45, Sandy Ridge, Walden Road, Chislehurst, Kent.
Stephenson, J. C., The Dental Hospital, Lower Maudlin Street, Bristol 1, Gloucestershire.
Stevenson, Wm., The Threshold, 145, Bo'ness Road, Grangemouth, Stirlingshire, Scotland.
Stobie, C. W., Hillberry, Austenwood Lane, Gerrards Cross, Buckinghamshire.
Strange, Mrs. M. C., Tower House, Newmarket, Beccles, Suffolk.
Stubley, R., 77, Elmfield Road, Gosforth, Newcastle upon Tyne 3, Northumberland.
Sullivan, P. G., 80, Wickham Road, Higham's Park, E.4.
Swann, A. J., 10, High Street, Chippenham, Wiltshire.
Swift, P. A., Langsmead, Uxbridge Road, Hayes, Middlesex.
Tait, R. V., 62, Nightingale Road, Rickmansworth, Hertfordshire.
Tanner, Mrs. P. M., Quantock, 21, Meadway, Berkhamstead, Hertfordshire.
Tata, F. R., 10, Sylvester Avenue, Chislehurst, Kent.
Taylor, Miss B., 10, Malone Road, Belfast 9, Northern Ireland.
Taylor, G. S., 33, Northover Road, Bristol, BS9 3LN.
Thomas, G. D., 63, Sketty Road, Swansea, SA2 0EN.
Thomas, R. J., 3, Upper Lemon Street, Truro, Cornwall.
Thomson, Mrs. C. M., 166, Garscadden Road, Glasgow, W.5, Scotland.
Thurston, Mrs. A., The Malverns, Cherry Tree Road, Rowledge, Farnham, Surrey.
Tibbatts, Mrs. M. A., Monkspath Hill Farm, Stratford Road, Hockley Heath, Solihull, Warwickshire.
Timms, D. G., Royal Infirmary, Preston, Lancashire.
Tipnis, A. K., 'Crowder', 28, Manley Road, Ben Rhydding, Ilkley, Yorkshire, LS29 8OP.
Tittle, J. J., 4, Red Gabbs Court, White Hill, Bletchingley, Redhill, Surrey.
Townend, P. I., Orthodontic Department, City General Hospital, Carlisle, Cumberland.
Trend, J. P., 22, Green Dragon Lane, N.21.
Tulley, Prof. W. J., 36, Meadow Way, Farnborough Park, Kent, BR6 8LW.
Tulloch, Mrs. J. F. C., 31, St. Peters Street, Islington, N.1.
Turner, Mrs. B. M. A., Orchard House, 25 Bollin Hill, Wilmslow, Cheshire.
Upson, N., 10, Chamberlain Way, Surbiton, Surrey.
Usiskin, L. A., 11, Linden Lea, N.2.
Valentine, L. H., 180, South Street, Romford, Essex RM1 1TR.
Viader, P. H. J., 80, Cathedral Road, Cardiff, Glamorganshire, Wales.
Vig, P., 3, Brooklands Park, Blackheath, S.E.3.
Vig, Mrs. P., 3, Brooklands Park, Blackheath, S.E.3.
Wallis, R., Buckingham House, Graham Road, Malvern, Worcestershire.
Walsh, E. A., 2, Tycehurst Hill, Loughton, Essex.
Walther, Prof. D. P., Orthodontic Department, Royal Dental Hospital, Leicester Square, W.C.2.
Ward, Mrs. A. D., 186, Wricklemarsh Road, S.E.3.
Warner, Miss D. E. M., 6, Rushmore Close, Rickmansworth, Hertfordshire.
Watkins, B. N., 2, Victoria Street, Stourbridge, Worcestershire.
Webb, W. G., 3, Eynsford Rise, Eynsford, Dartford, Kent.
Webster, Miss E. M., Birnam, 432, Crow Road, Glasgow W.1, Scotland.
Wein, M., 56, Kingsland High Street, E.8.
Welton, Mrs. A. M., Walton, Ryders By, Northall, Dunstable, Bedfordshire.
Westbrook, E. A., 79, Harley Street, W.1.
White, Miss B. E. E., 40, London Road, Southborough, Tunbridge Wells, Kent.
White, Prof. T. C., 'Five Acres', Bucklyvie, Stirlingshire, Scotland.
Whitelegg, J. G., Toad Hall, Forest Row, Sussex.
Whitfield, P. F. G., 46, Hyde Road, Paignton, Devon.
Whittaker, L. B., 25, Old Orchard Road, Eastbourne, Sussex.
Widdowson, A. R., 41, Caldy Road, West Kirby, Wirral, Cheshire.
Wilkie, J. K., 89a, Redland Road, Bristol 6, Gloucestershire.
Willcocks, R. W., 4, Upper Wimpole Street, London, W1M 7TD.
Williams, D. W., 4, Devonshire Road, Harpenden, Hertfordshire.
Williams, J. K., 67, Thornton Road, S.W.12.
Williamson, M. M., 49, Quay Road, Ballycastle, Co. Antrim, Northern Ireland.
Wilson, A. J., 84, Rodney Street, Liverpool 1, Lancashire.
Wilson, C. P., 40, Kingsley Road, Northampton, Northamptonshire.
Wilson, H. E., 78, Harley Street, W.1.
Wilson, R. A., 24, Prideaux Road, Eastbourne, Sussex.
Wilson, T. G. B., 12, The Avenue, Colchester, Essex.
Winter, Prof. G. B., Eastman Dental Hospital, Gray's Inn Road, W.C.1.
Wongtschowski, K. G., 45, Wimpole Street, W.1.
Wood, N. J., 2, Clarendon Road, Bournemouth, Hampshire.
Wood, T. Jason, 241, Manningham Lane, Manningham, Bradford 8, Yorkshire.
Woods, A. R. H., 4, Manor Place, Edinburgh 3, Scotland.
Woodward, H. A., 25, East Street, Havant, Hampshire.
Wreakes, G., 11, The Chine, Echo Barn Lane, Farnham, Surrey.
Wynne, Dr. T. H. M., Orthodontic Department, Liverpool Dental Hospital, Pembroke Place, Liverpool 3, Lancashire.
Zaufal, S. J., 6, Netherfield Road, Beeson End, Harpenden, Hertfordshire.

CORRESPONDING MEMBERS

Aamodt, A. C., Øvre Storgt 4/6, 3000, Drammen, Norway.
Abensur, Dr. J., Prolg. Benavides 1080–Of. 1, Urb. San Antonio–Miraflores, Lima, Peru, South America.
Ahlgren, Dr. J., Faculty of Odontology, University of Göteborg, S-40033 Göteborg 33, Sweden.
Ashby, J. W., Harley, 137, Cambridge Terrace, Christchurch, New Zealand.
Bakatselos, S., 79, Egnatia Street, Thessoloniki, Greece.
Bell, Dr. L. A., Bo Pine Apt. F4, Concord, California, 94520, U.S.A.
Bell, W. P. L., 4, Martin Avenue, Remuera, Auckland, S.E.2., New Zealand.
Blausten, Dr. Sam, 90, Conklin Street, Farmingdale, L. I., New York 11735, U.S.A.
Bolton, G. H. P., 246, Queen Street, Brisbane, Queensland 4000, Australia.
Bowden, B. D., 145, Collins Street, Melbourne, Australia.
Braude, B., 78, Pasteur Chambers, Jeppe Street, Johannesburg, South Africa.
Brears, Dr. O. B., Anglo-Ecuadorian Oilfield Ltd., Guayaquil, Casilla 4614, Ecuador, South America.
Carpenter, I. P., 137, McClennan Road, Ottawa 6, Ontario, Canada.

Chan, B. K., Government Dental Clinic, Ipoh, Perak, Malaysia.
Cheah, C. K., Y.L. Lee Building, Overseas Union Bank Ltd., 4th Floor, Mountbatten Road, Kuala Lumpur, Malaysia.
Choo, Soo Bin, Government Dental Clinic, Ipoh, Perak, Malaysia.
Choo, T. C., Suite E1, 5th Floor, Macdonald House, Orchard Road, Singapore 9.
Cook, C. C., Queen Street, Masterton, New Zealand.
Copeland, G. P., 130, Drinkwater Street, Sudbury, Ontario, Canada.
Costello, M. J., Suite 45, Civic Arcade, 48–50 George Street, Parramatta, New South Wales 2150, Australia.
Coval, Dr. N. M., 30, Westover Place, Lawrence, L.I., New York, U.S.A.
Cox, Dr. N. J., T. & G. Building, 201, Elizabeth Street, Sydney, Australia.
Crabb, J. J., F.C.O. (Rangoon), King Charles Street, S.W.1.
Crisp, B. C., 217, North Tee, Adelaide, South Australia.
Croll, Dr. R. O., 620, View Street, Victoria, British Columbia, Canada.
Demajo, A., 26, Merchants Street, Valletta, Malta.
Démogé, P. H., 29–33, Avenue Raymond Poincaré, Paris 16e, France.
De Muelenaere, J. J. G. G., 985, Church Street, Arcadia, Pretoria, South Africa.
De Villiers, J. F., P.O. Box 63, Tiervlei, Cape Town, South Africa.
Eastwood, A. W., University of Western Ontario (Dental), London, Zone 72, Ontario, Canada.
Engh, Olav, Hammerstadgt, 21b, Oslo, Norway.
Fainsinger, B. E., 401, Salbany, Albany Grove, Durban, South Africa.
Franklin, G., Medical Building, Drummond Street, Montreal 25, Quebec, Canada.
Fransblow, P., Georgia Medical-Dental Building, 925, West Georgia Street, Vancouver 1, British Columbia, Canada.
Ghosh, A. S., 54, Chowringhee, Calcutta, India.
Gilbert, G. H., Victoria Chambers, 9, Victoria Street, Christchurch, New Zealand.
Goldstein, M. C., 950, West Peachtree Street, Atlanta, Georgia, U.S.A.
Gonzalez, R., Suarez Guerra 42, Santa Cruz, Tenerife, Canary Islands.
Gosman, S. D., Orthodontist, 109, South Union Avenue, Margate, New Jersey 08402, U.S.A.
Gottlieb, A. W., 3, Oswega Avenue, Long Beach, New York 11561.
Granerus, R., Kungsportsavenyen 20, Gothenburg, Sweden.
Granse, K. A., Mariedalsvagen 25, Malmö, Sweden.
Grossman, R. C., 6325, Topanga Canyon Boulevard, Woodland Hills, California 91364, U.S.A.
Gugny, G., 20, Rue de Mogador, Paris 9e, France.
Hackie, T. J., 1636, Pendosy Street, Kelowna, British Columbia, Canada.
Hargreaves, Prof. J. A., Faculty of Dentistry, 124, Edward Street, Toronto 101, Ontario, Canada.
Harkness, E. M., c/o University of Otago Dental School, P.O. Box 647, Dunedin C.I., New Zealand.
Heath, J. R., 18, Collins Street, Melbourne, C.1., Victoria, Australia.
Hotz, Prof. R., Zahnarztliches Institut, Plattenstrasse 11, Postfach 163, 8028, Zurich, Switzerland.
Johannesen, Børge, Dronningens Gate 23, 7000, Trondheim, Norway.
Kaplan, R., c/o Department of Orthodontics, The University of Washington, Seattle, Washington 98105, U.S.A.
Krogstad, Olav, Jun., Kjeveortopedisk Avd., Norges Tannlegehogskole, Oslo, Norway.
Lang, E. T., Broome's Building, Devon Street, New Plymouth, New Zealand.
Lee Chin Kung, Government Dental Clinic, Grove Road, Penang, Malaysia.
Leong, C. T., Government Dental Clinic Puda Road, Kuala Lumpur, Malaysia.
Lervy, Major W. K., (R.A.D.C.) British Military Hospital Munster, B.F.P.O. 17 (B.A.O.R., Germany).
Ljungdahl, L., Ytterwägen 7, Kristianstad, Sweden.
Lopez R., H. R., P.O. Box 3019, La Paz, Bolivia, South America.
Lundström, Prof. A., Stureplan 19, Stockholm, Sweden.
Lye Thim Loke, Mrs., 75, Cairnhill Circle, Singapore 9.
Lyn, M. R., 16, Tangerine Place, Halfway Tree, Kingston 10, Jamaica, W.1.
McAnuff, R. M., c/o Medical and Health Department, Hamilton, Bermuda.
McDonald, J. D. H., Orthodontic Department, Dental Hospital of Melbourne, Elizabeth Street, Melbourne, Victoria, Australia.
Magni, F., via Cesarea, 5/12a, Genoa, Italy.
Mak, K. L., 16, Wilson Road, 1st Floor, Jardine's Lookout, Hong Kong.
Manara, G., 23, Point Street, Sliema, Malta.
Max, R. P., 120, Remuera Road, Auckland 5, New Zealand.
Marcovic, Prof. M., Ustanicka 129, 11000 Belgrade, Yugoslavia.
Melville, R. G., 503, Medipark, Hertzog Boulevard, Cape Town, South Africa.
Miller, B. H., 911, Medical Centre, Mediesesentrum 911, Kaapstad, Heerengracht, Cape Town.
Mizrahi, Dr. E., 1001, Medical Arts Building, Jeppe Street, (Cor. Troye St.), Johannesburg, South Africa.
Moss, G. W., 1209, Wilcox Drive, Kingsport, Tennessee, U.S.A.
Mulligan, W. O., 115, Hazen Street, Saint John, New Brunswick, Canada.
Norton, R. Y., St. James Buildings, 109, Elizabeth Street, Sydney, New South Wales, Australia.
Nugent, M. A. C., c/o The University of Adelaide, Department of Dental Science, Adelaide, S.A. 5001, Australia.
Oliver, H. T., 1414, Drummond Street, Montreal 25, Quebec, Canada.
O'Meyer, R. X., 267, Rue St. Honore, Paris, 1er, France.
Onn Lee Chee, Institute of Health, Outram Road, Singapore 3.
Oosthuizen, L., 631, Robert Koch Medical Building, Pretorius Street, Pretoria, South Africa.
Panzer, Dr. Milton, 2001, Colchester Road, Flint, Michigan, 48503, U.S.A.
Pasikov, Dr. S., 380 Washington, Glencoe, Ill. 60022, U.S.A.
Patel, V. B., 39, Chowringhee Road, Calcutta 16, India.
Paton, Miss D. A., R.A.M.C. Officers' Mess, British Military Hospital, Rinteln, B.F.P.O. 29 (B.A.O.R., Germany).
Pihl, Miss E. M. K., St. Clemensgatan 32, Hälsingborg, Sweden.
Ping, S. T., Orthodontic Unit, Government Dental Clinic, Jalan Gambut, Kuantan, Pehang, Malaysia.
Pinsker, Dr. L. J., Lakewood Dental Center, 5464, South Street, Lakewood, California, U.S.A.
Reading, J. F., Park House, 187, Macquarie Street, Sydney, Australia.
Robertson, D. E., c/o J. A. Hartley, 89, Outlook Crescent, Bardon, Queensland 4065, Australia.
Robson, F. F., Robinson House, Union Avenue, Salisbury, Rhodesia, Africa.
Rogers, P. J., 3rd Floor, Macquarie House, 173, Macquarie Street, Hobart, Australia.
Roy, B. C., Maternal and Child Health Clinic, Maxwell Road, Kuala Lumpur, Malaysia.
Sachs, N. J., 84-75, 168th Street, Jamaica, 11432, New York, U.S.A.
Schleimer, Dr. Max, Lakewood Dental Center, 5464, South Street, Lakewood, California, U.S.A.
Schouker-Jolly, M., 170, Rue Ordiner, Paris, 18, France.
Spring, D. F., Gilbert Court, 100, Collins Street, Melbourne, C.1, Victoria, Australia.
Sundararaj, Mrs. S., 1881, Jalan Bukit, Bukit Mertajam, Malaysia.
Tam, M. F., Room 407, 4th Floor, Loke Yew Building, 4, Jalan Belanda, Kuala Lumpur, Malavsia.

Tegner, G., Drottninggatan 62, Hälsingborg, Sweden.
Tippett, I. D., 21, Lynette Avenue, Beaumaris, Victoria, Australia.
Toutountzakis, N., 2, Anaxandrou Street, Athens 454, Greece.
Tsaltas, G. K., 15, Arachous Street, Athens, Greece.
Tsang, Y. S., 63, Robinson Road, 3rd Floor, Hong Kong.
Valentine, H. B., 9, Ward Street, Lower Hutt, New Zealand.
Volmer Lind H. C., Ortodonipolikliniken, Halmstad, Sweden.
Watson, D. C., 167, St. George's Terrace, Perth, Western Australia.
Wenck, R. D., 301, Margaret Street, Toowoomba, Queensland, Australia.
West, V. C., 5, Seattle Street, North Balwyn, 3104, Victoria, Australia.
Willis, L. E., Lister Building, Auckland, C.I., New Zealand.
Yin-Cheung Wu, S., Room 104, Hing Wai Building, 36, Queen's Road C., Hong Kong.
Yip, A. S. G., 14, Paradise Bay, Winnipeg 20, Manitoba, Canada.

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Plymouth
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Durham

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Sunderland
Dixon, D. A.

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Laxton, L.
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Wilson T. G. B.
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Great Tey
Keniry, A. J.
Leigh-on-Sea
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Loughton
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Valentine, L. H.
Theydon Bois
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Westcliff-on-Sea
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Woodford Green
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Gloucestershire

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Peace, Mrs. H. C.
Potokar, S. L.
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Cirencester
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Frampton-on-Severn
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Hampshire

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Havant
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Portsmouth
Dickson G. C.
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Townend, B. R.
Ryde (Isle of Wight)
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Winchester
Broadway, R. T.

Herefordshire

Hereford
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Hertfordshire

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Bishop's Stortford
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Dodd, Miss J. M.
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Bushey Heath
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Williams, D. W.
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Radlett
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Redbourn
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St. Albans
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Huntingdon

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Kent

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Biggin Hill
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Birchington
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Dartford
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Dover
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Farnborough Park
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Gillingham
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Knockholt
Metcalf, J.
Orpington
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Sandwich
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Sevenoaks
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Page, G. S.
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West Wickham
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Lancashire

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Liverpool
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Manchester
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Oxfordshire
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Oxford
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Langport
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Staffordshire
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Wolverhampton
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THE VALUE OF PROPHECY IN ORTHODONTICS

B. C. LEIGHTON, M.D.S., F.D.S., H.D.D., D.D.O., D.Orth.
King's College Hospital Dental School, London

'*Ζυμβουλον αναμεινασ χρονον*', 'Be ruled by time, the wisest counsellor of all.' So said Pericles, ruler of Athens, to an impetuous young general called Tolmides when trying to dissuade him from rushing into an invasion of Boeotia without considering carefully the timing of the attack. The advice went unheeded, and was not appreciated by the Athenians until Tolmides had been killed and the battle lost. It was characteristic of Pericles who is reported to have achieved his success by a mastery of the art of timing when dispensing his administrative reforms. This may seem to be remote from a discussion on orthodontics but a connexion will be demonstrated during the course of this paper.

Russell Marsh (1948), in discussing the relative merits of simple and complex appliance therapy, indicated strongly his feeling that simplification of appliance therapy was usually very desirable, and prophesied a trend in this direction ' as soon as we accept that all who are in need of treatment should receive it '. Since Russell Marsh was not only my uncle but also my teacher it is perhaps not surprising that I should hold similar views. I have therefore set myself the task of encouraging the fulfilment of this prediction. During the next half-hour I hope to offer more convincing support for this prophecy than was shown by a medieval physician called Cartano, in forecasting that King Edward VI of England would live to the age of 55 years. When the King died at the age of 16, Cartano had no option but to predict the date of his own death and ensure its accuracy by committing suicide.

Prevention may not be so glamorous and dramatic as treatment of an established condition, but it is an ideal whose attainment should be borne in mind by every member of the dental profession. It is likely to be restricted in its scope in orthodontics for some time to come because knowledge of the aetiology of malocclusion and ability to predict its course of development is limited. However, it is often possible to simplify treatment by very careful selection of the age at which it is started, facilitating guidance of the process of development with as little interference as possible. The value of careful timing is perhaps best seen when planning the extraction of first permanent molars. It is easy to recall cases where ill-timed extractions have left a severe malocclusion of the second molars. On the other hand, in favourable cases early extraction may permit quite good alinement of the remaining teeth. Radiographs of identical twins show the effect of timing on the alinement following extraction of first molars (*Fig.* 1). In one twin the first molars were extracted at 10 years whereas her sister's teeth were removed 2 years later. In *Case* 73 (*Fig.* 2) all the first molars were extracted at 10 years but a root of the lower right molar was left and not removed until 2 years later.

I should like to suggest that it is good orthodontics to foster such potential as the patient has for normal development, by removing obstructions to the development of normal occlusion with a minimum of forced tooth movement. There are, of course, some conditions which depart so far from normal occlusion that they require more compulsive orthodontic treatment, achieved either by means of fixed appliances or by means of surgical therapy. They are not usually difficult to identify at an early age.

To the young embryo orthodontist a well organized system of diagnosis and treatment planning appears very attractive. It is even more so if the appliance therapy is of a stereotyped nature in which mastery of one technique, albeit demanding of a high standard of manual dexterity, will suffice for the treatment of all cases. Such philosophies ignore the fifth dimension of growth, namely, individual variation, and seek to place all individuals into a common developmental mould. If one accepts that all patients should conform to a common standard of normality, then precise placement of teeth into a geometrically planned pattern is desirable, and can best be achieved by means of a versatile and irresistible appliance. If, on the other hand, one recognizes that there is an infinite variety of

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patterns of development, then it is clearly better to treat each patient as an individual. This requires an understanding not only of the general pattern of development of all children but also the possible extent of variation between individuals, if intelligent predictions of future development are to be made. To the beginner this is a most formidable task, for it demands knowledge which can be obtained only from careful observation over many years. It is, moreover, a difficult aspect of orthodontics to teach, because it does not easily lend itself to organized courses of instruction. In spite of the difficulties, a better understanding of development and its variations must be a major objective of orthodontists during the remainder of this century. By its very nature it must be an extended study planned to provide results many years after it has started.

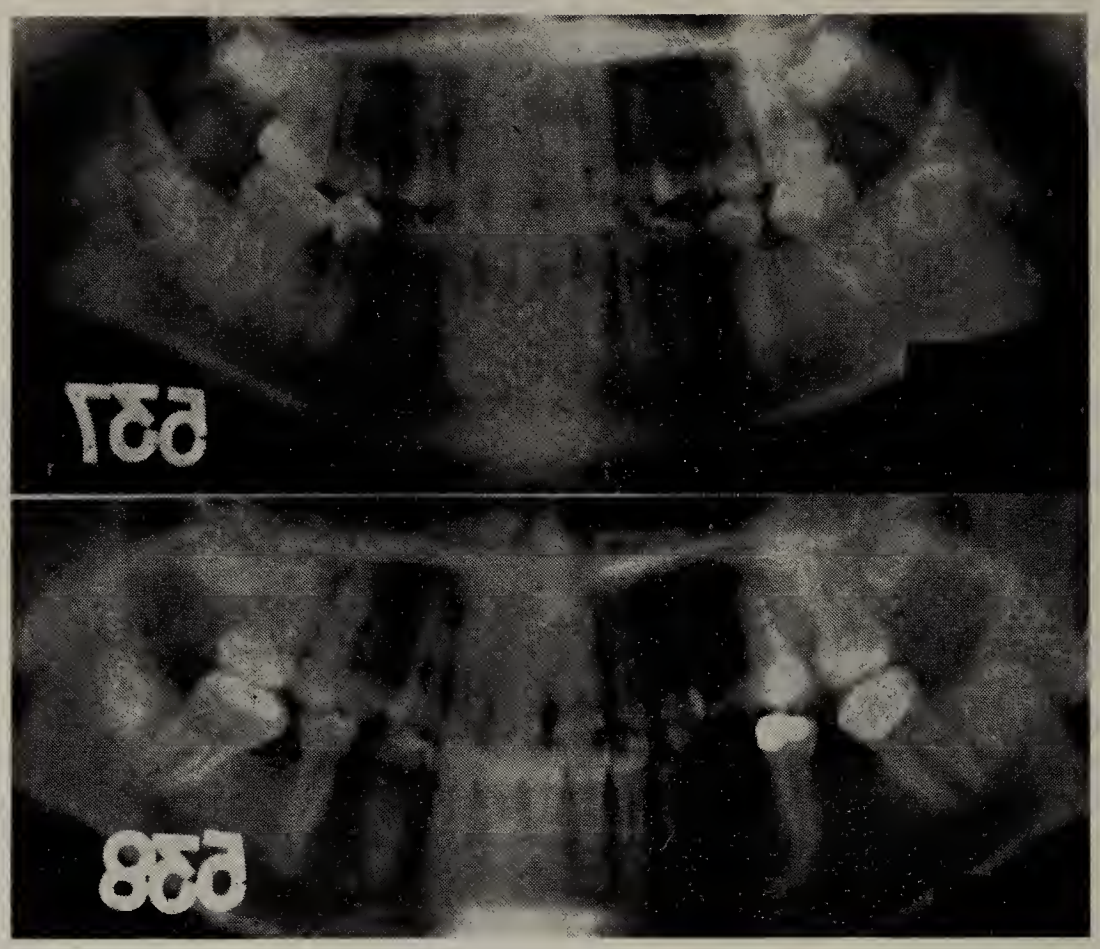


Fig. 1.—Orthopantomogram radiographs of identical twin girls from whom first molars have been extracted at different ages. The position of the second molars is very much better in one twin (*above*) when the molars were removed at 10 years, 2 years earlier than in the other twin (*below*).

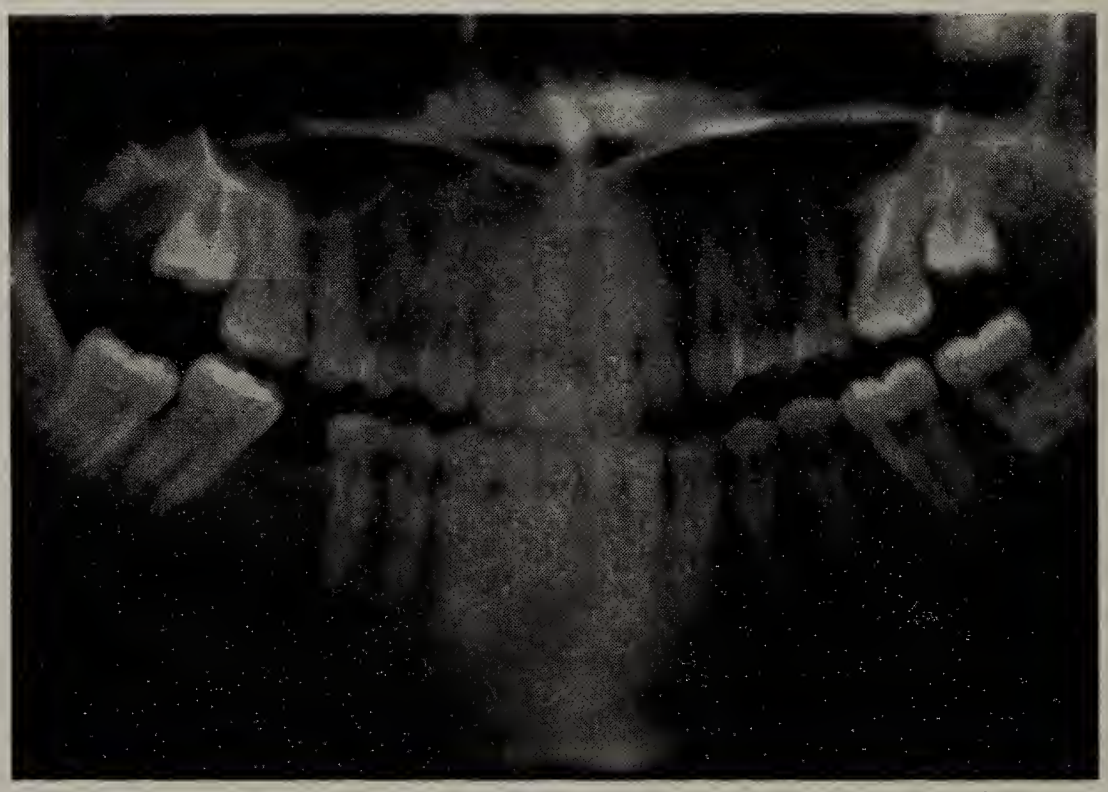


Fig. 2.—*Case* 73. Orthopantomogram radiograph showing how, although all first molars were extracted at the age of 10 years, failure to remove a root until 2 years later prevented closure of the lower right first molar space.

THE SAMPLE

The factual observations in this paper are based to a large extent on the records of a sample of children who have been under observation since birth. The sample contained originally 529 subjects, but loss has now reduced this number to 90. These have now all passed the age of 16 years. Although these studies have not shed much light on the aetiology of malocclusion, they do give information upon its earliest manifestation in the dentition, and indicate strongly that this is an approach that is well worth pursuing further.

There are two broad aspects of the development of occlusion which should be the subject of prediction before treatment is planned. The first is the arch relationship which may be expected at maturity, and the second is the alinement of the teeth within each jaw. The latter is affected by a variety of local conditions, but is largely determined by the degree of crowding present.

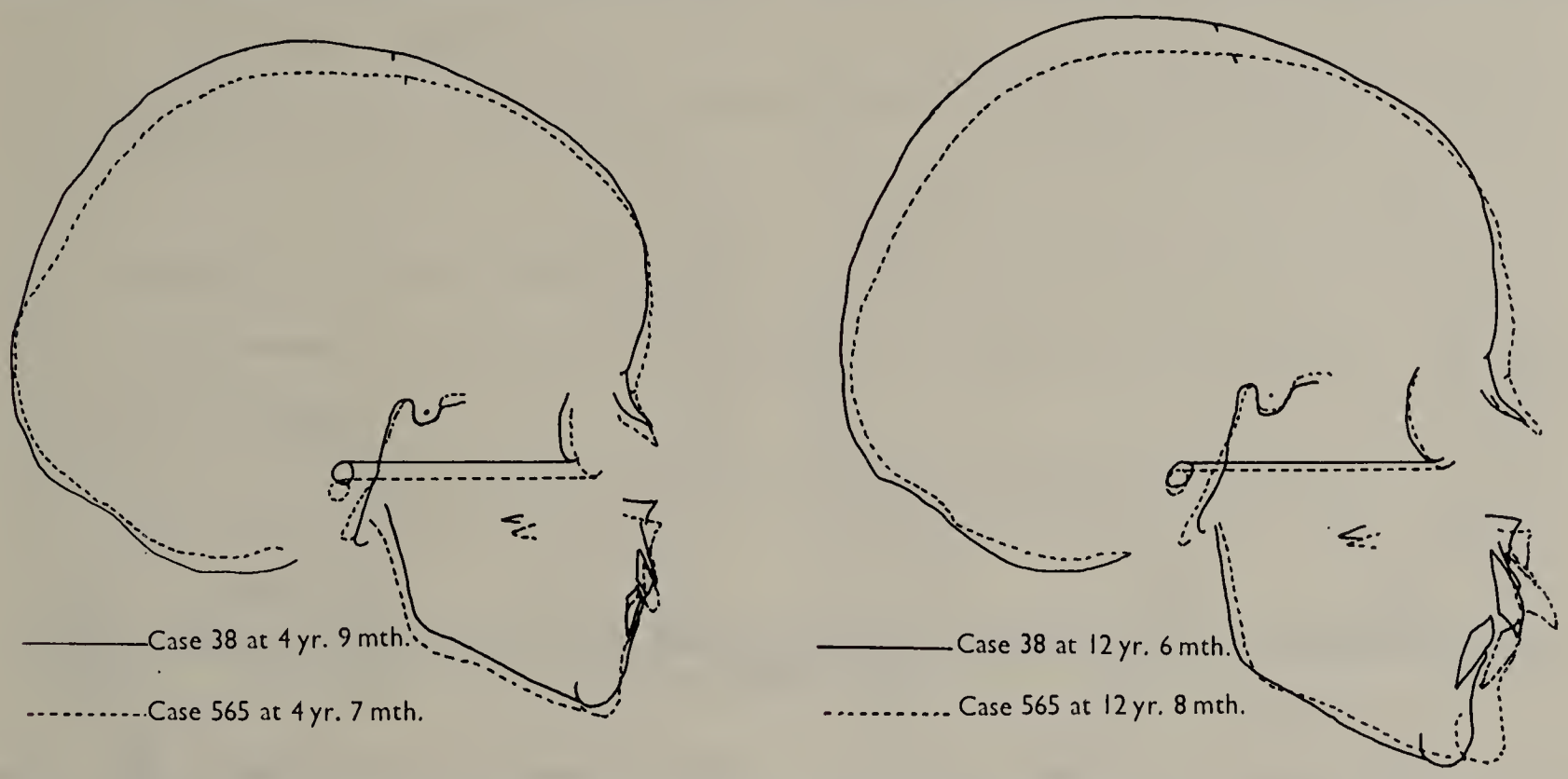


Fig. 3.—Cephalometric tracings of 2 sisters superimposed at the ages of $4\frac{1}{2}$ and $12\frac{1}{2}$ years to show how divergence of facial form is caused by different types of growth.

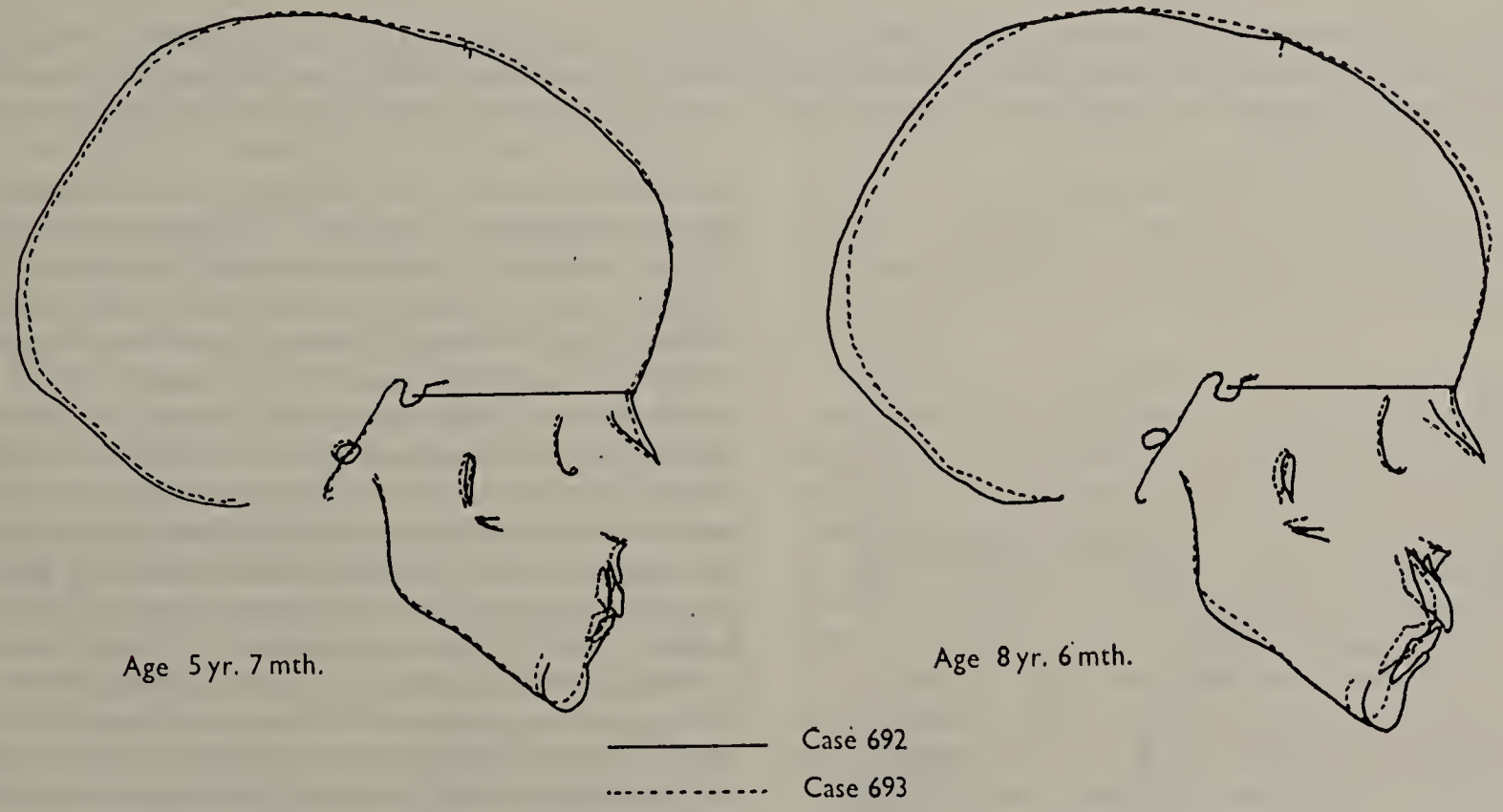


Fig. 4.—Cephalometric tracings of twin girls superimposed at the ages of $5\frac{1}{2}$ and $8\frac{1}{2}$ years to show how divergent growth increases the difference between the two girls.

ARCH RELATIONSHIP

Extreme deviations of anteroposterior jaw relationship are usually easy to predict, as soon

as the deciduous dentition is established. There is, however, rather more difficulty in giving a prognosis for mild degrees of postnormal occlusion. This is well illustrated in the case of 2 sisters whose cephalometric tracings at the age of $4\frac{1}{2}$ years appeared to be very similar when superimposed on point 'S' and oriented to the Frankfurt plane (*Fig.* 3). By the age of $12\frac{1}{2}$ years, however, quite obvious differences are apparent. In *Case* 38 facial growth has been almost entirely in a vertical direction, whereas in *Case* 565 growth has been rather more forward

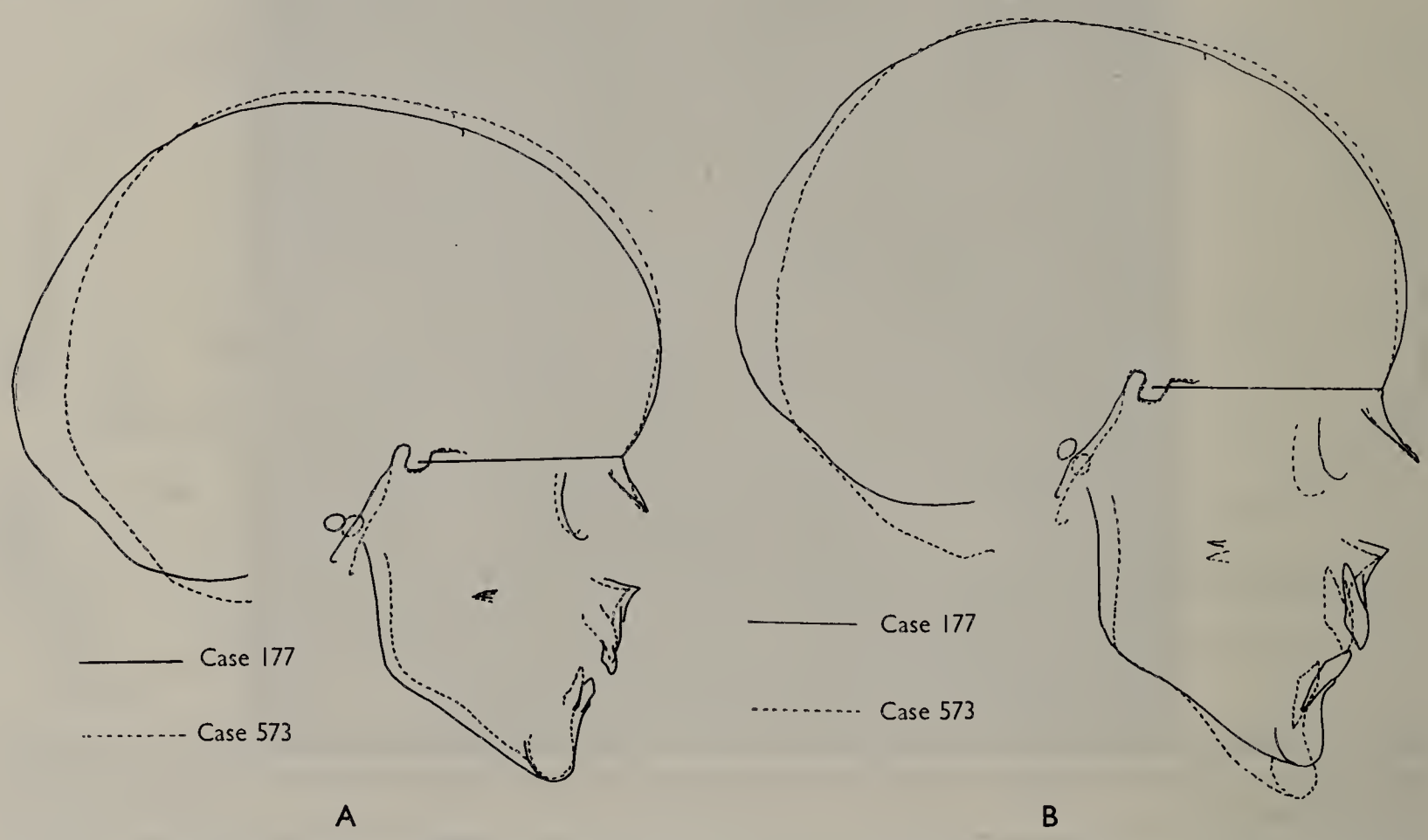


Fig. 5.—A, Superimposed tracings of 2 unrelated children who appeared to present a similar problem at the age of $6\frac{1}{2}$ years. B, Difference of subsequent growth was associated with a poorer prognosis for the case showing most vertical growth at 15 years (*Case* 573); at $6\frac{1}{2}$ years this case had a slightly shorter face.

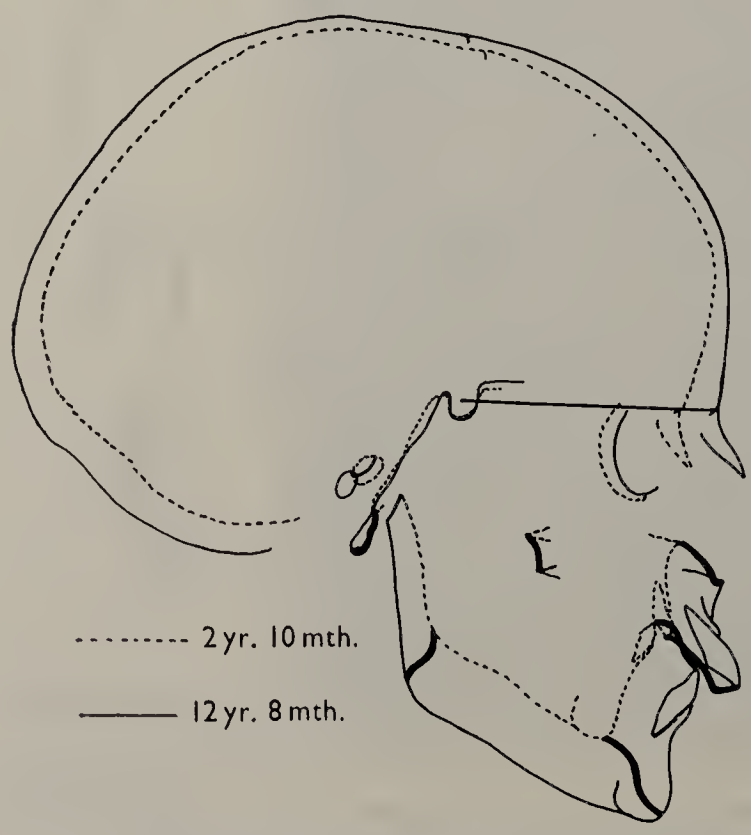


Fig. 6.—Superimposed tracings of a girl at 2 years 10 months and 12 years 8 months on which intermediate annual migrations of certain fixed points are plotted. It will be noted that these do not follow straight line courses. This may represent some disadvantages to superimposing on the S.N. plane.

than downward. A similar phenomenon is demonstrated by tracing of 2 female twins (*Fig.* 4). At the age of $5\frac{1}{2}$ years the outlines appear very similar, but 3 years later there are obvious differences. Although their appearances are very similar, *Case* 692 was always larger than her sister and not only grew at a faster rate but also showed more forward growth. This increasing variability as growth proceeds is to be found in many aspects of development and is probably an expression of the full blossoming of genetic potential coupled with the superimposed effect of longer and longer exposure to environment. Attention was drawn to this by Bhatia (1971) in an interesting report to this society earlier this year. He had found that not only do the mutual angular relationships of the horizontal planes of the face vary from one individual to another, but also that the relationships in each case change with age, and these changes are by no means constant. As a result there is found an increasing degree of variation in the mutual inclination of these planes with age. The mandibular plane in particular showed very great variability as age advanced. This is perhaps not surprising when it is remembered that the position of the gonion on the tracing is determined largely by muscle

influences, a factor which is not likely to affect greatly the S.N., Frankfurt, and maxillary planes.

It is often said in textbooks that a large Frankfurt-mandibular-plane angle is an unfavourable sign when determining the prognosis (White, Gardiner, and Leighton, 1967). By and large it may be accepted that the large Frankfurt-mandibular-plane angle is the product of growth in a predominantly vertical direction, and a small angle the end-product of growth in a forward direction. Although it is quite easy to identify such cases when they are fully grown, it is much more difficult in the deciduous dentition phase. The tracings of 2 unrelated children at the age of $6\frac{1}{2}$ years have been superimposed to demonstrate their similarity (*Fig.* 5). Both cases had sucking habits and a tendency to postnormal occlusion. By the age of $15\frac{1}{2}$ years there was a very marked difference in the direction of facial growth, *Case* 573 showing a much greater amount of vertical growth. Both children received orthodontic treatment to correct the incisor relation, and as might have been expected there was some relapse in the case showing the larger amount of vertical growth. No doubt it will be possible at some time in the future to predict the direction of facial growth by analysing changes in profile tracings over a period of 2 or 3 years. Such techniques are usually based upon the assumption that growth will continue to proceed in a predictable direction. The work of Bhatia (1971) suggests that there is a much greater degree of individual variation than is suggested by an examination of the averages of a sample. Further difficulty is presented by changes that may take place in the orientation of the planes of reference. A suspicion of this possibility is shown by a tracing in which annual movement of certain landmarks is plotted (*Fig.* 6). It is possible that deviations in the paths followed by the gonion, the gnathion, and the anterior nasal spine could have been produced by slight changes in the position of point 'S'. Observation over too short a period could quite easily suggest a deceptive prognosis. A grid depicting the average course of vertical growth may be used as a means of assessing the trend of a particular case. It is necessary for this purpose to separate male from female subjects (*Fig.* 7). Such grids were prepared from the records of 14 male and 17 female cases who had been followed from the age of $5\frac{1}{2}$ years. The cases were not selected on any other basis than the availability of complete records, and included malocclusions, although there were no major malformations. By placing the grid over the serial tracings of the individual it is possible to see at a glance how he departs from the average (*Fig.* 8). Where precocious or delayed development is suspected the grid may be moved to right or left to obtain a better fit.

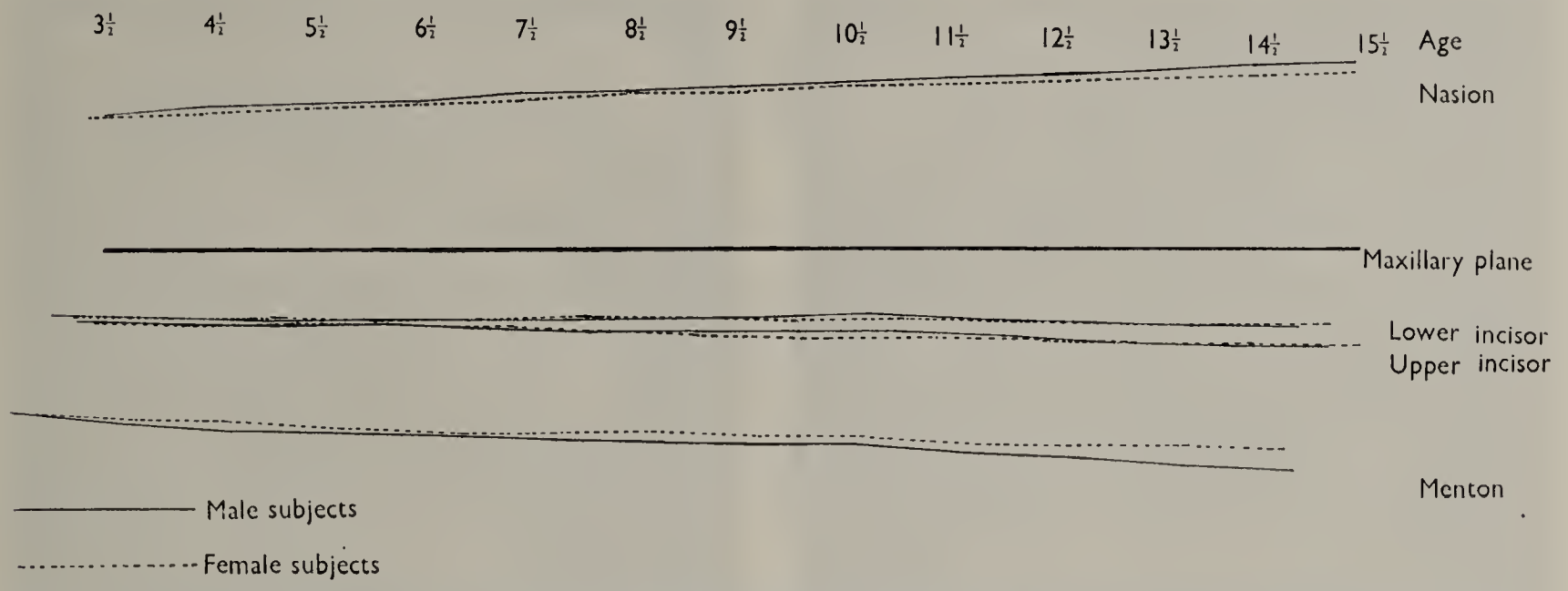
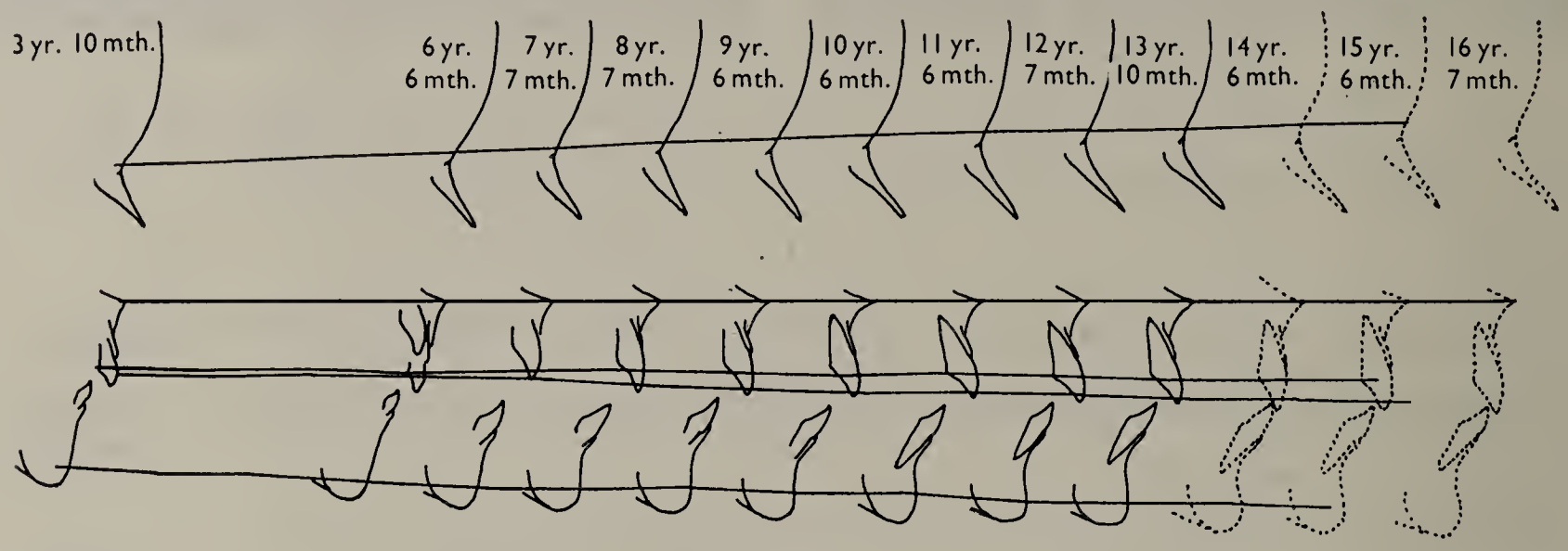


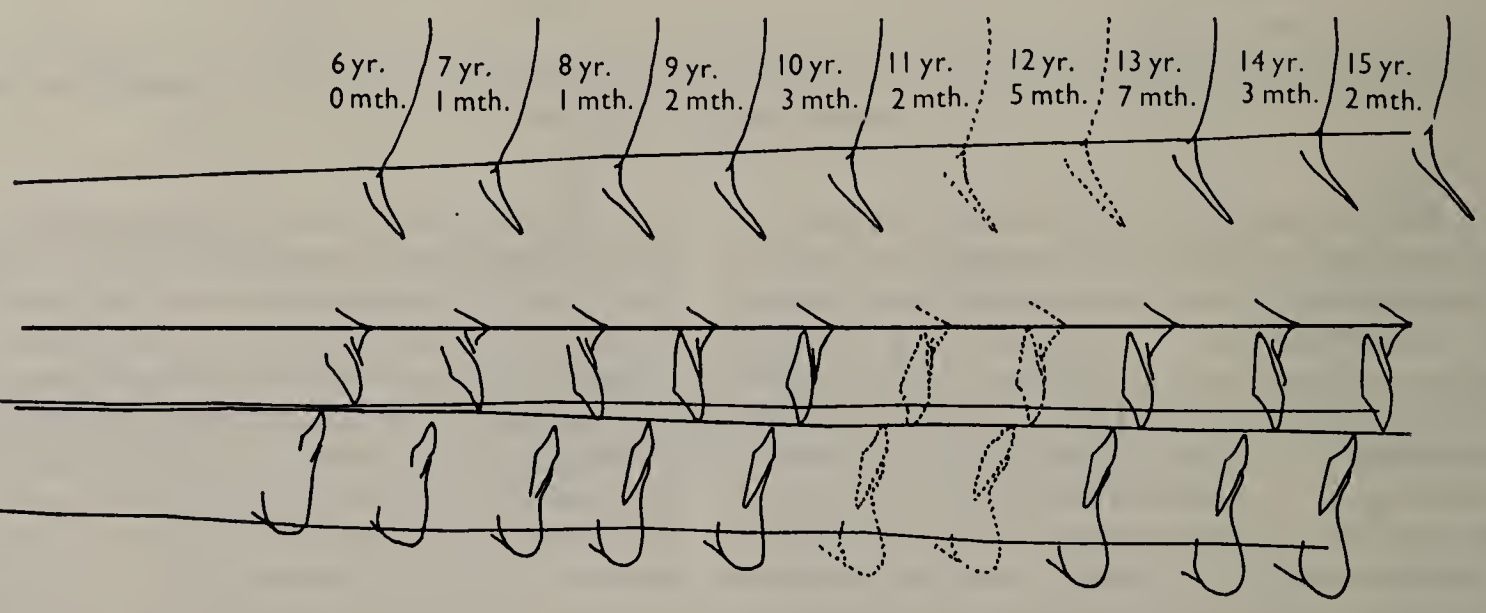
Fig. 7.—Superimposed grids for male and female subjects showing yearly change of mean dimensions of vertical height of the face.

It has been suggested that early postnatal development of the jaws is of particular importance to the orthodontist because it is the age at which malocclusion is first detected. This view was expressed very clearly by our first President, J. H. Badcock (1933), when addressing the Second International Orthodontic Congress with the following words: 'Irregularities of the second set of teeth are foreshadowed in the first, and even at birth future malrelation of the jaws may often be detected.' Although the first statement is largely true there is very little evidence to support the second. Examination of the gum-pads at birth reveals wide variation not only of size but also of relationship, both vertically and anteroposteriorly (*Fig.* 9). It is tempting to believe that these variations are related to the nature of subsequent malocclusion. In fact, longitudinal records of 100 cases offer very little evidence to support this suggestion. The vertical relationship of the gum-pads at birth, in particular, seems to have very little significance. On

the other hand, the presence of a deep incisor overbite in the mature deciduous dentition can be correlated quite closely with a similar overbite in the permanent dentition. This should be regarded, therefore, as an unfavourable sign at the age of 5 years. Prediction of the ultimate overbite is made difficult by the effect of sucking habits on the deciduous incisor relationship. An

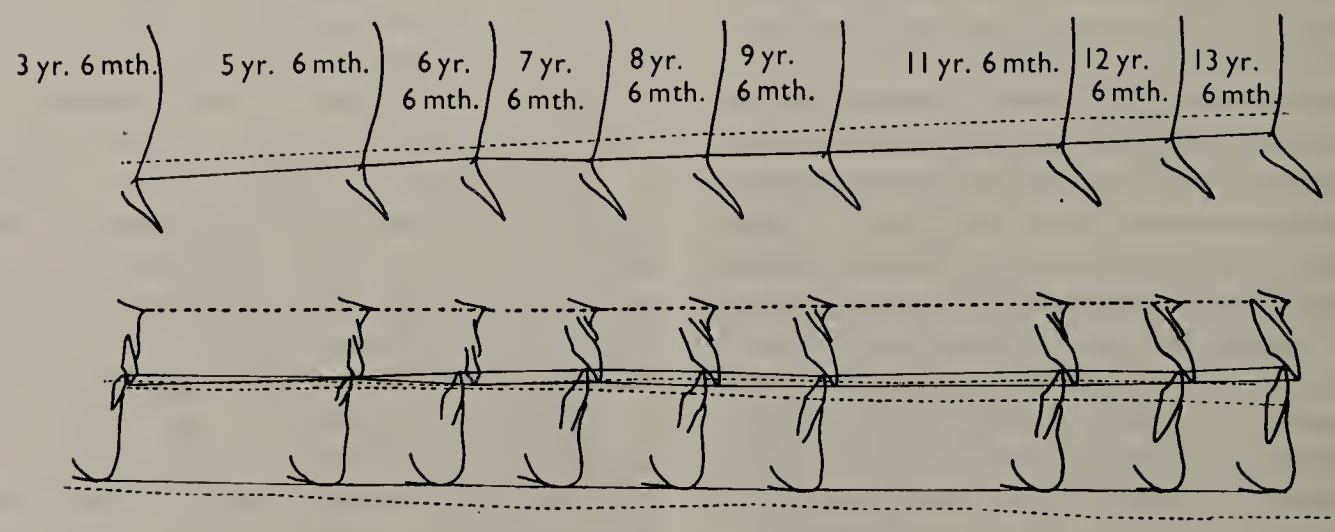


Case 177



Case 573

A



Case 322

B

Fig. 8.—A, Serial cephalometric tracings of the cases shown in *Fig*. 5. Superimposition of the tracings on the grid of average changes seen in female subjects shows how greater downward growth of *Case* 573 might have been used to predict the final difference between the two girls. Interrupted outlines indicate periods of treatment. B, Serial cephalometric tracings of a female patient in whom vertical growth in the lower part of the face is exceptionally small. The mean grid for girls is superimposed.

open bite at the age of 5 years is pathognomonic of a sucking habit but is only rarely followed by an open bite of the permanent dentition. Calculation of correlation coefficients between selected stages from birth and maturity ($15\frac{1}{2}$ years) shows hardly any correlation at birth, increasing to a strong correlation at $12\frac{1}{2}$ years (*Table* 1). Elimination of cases where sucking habits were indulged after the age of 3 years emphasizes the strength of correlation between the deciduous and permanent dentitions. It is perhaps pertinent here to point out the transient nature of the open bite which is produced by sucking habits. By comparing the overbite of children with and without sucking habits it was found that the maximum difference occurred at about the age of 4 years when the habit is most active, and again at about 8 years when eruption of permanent incisors is vulnerable to the effects of the habit (*Fig.* 10). As the habit is abandoned so the mean overbite gradually approaches that of the cases where no habit existed.



A B

Fig. 9.—A, Study models of two pairs of gum-pads at birth, representing extreme variations of antero-posterior relationships. B, Study models of gum-pads of twins, showing a marked difference of vertical space (overbite) anteriorly.

Table I.—Correlation Coefficients for Overbite between $15\frac{1}{2}$ Years and Representative Stages of Development*

Age (years)	Correlation Coefficient	
	Whole Sample	No Sucking Habits
Birth	0·02	0·07
$3\frac{1}{2}$	0·52	0·77
$5\frac{1}{2}$	0·64	0·73
$9\frac{1}{2}$	0·68	0·69
$12\frac{1}{2}$	0·80	0·84

* Based on the records of 49 cases from whom no permanent teeth had been lost. Twenty-six of the 49 had no sucking habit after the age of 3 years.

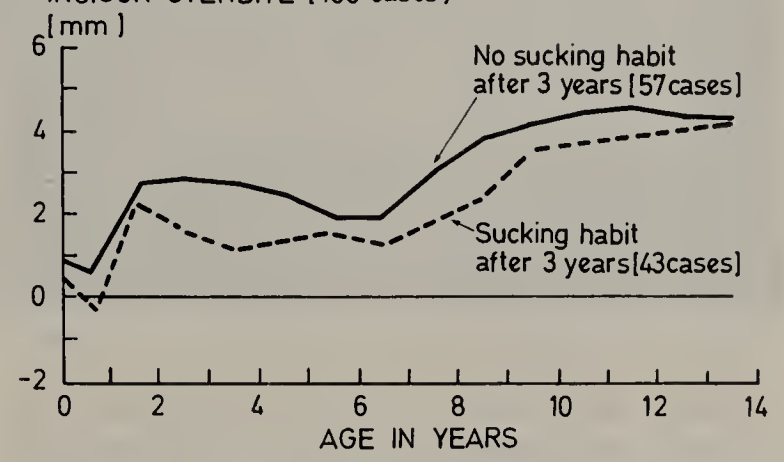


Fig. 10.—Graph to show changes of mean overbite between birth and $13\frac{1}{2}$ years in samples of children with and without sucking habits.

As with the overbite so the overjet at birth would appear to have little significance in predicting the future relationship of the dental arches (*Table II*). A case is now shown where the overjet at birth was particularly large (10 mm.) (*Fig.* 11). In spite of this it was followed by only a moderately postnormal occlusion. When cases with sucking habits are separated from the remainder it is found that although the habit causes an increase of overjet in the deciduous dentition phase this difference is almost eliminated by the age of 16 years (*Fig.* 12). Occasionally the incisor overjet at the time of eruption of permanent incisors is sufficiently large for the

lower lip to lie palatally to the erupting incisors. In these cases the incisor overjet will be increased by the presence of the lower lip which causes proclination of the upper incisors.

Lewisohn (1958) in discussing types of prediction said: ' As a rule of thumb, we can say that long term predictions are easier to make whenever we deal with aggregates which may balance out, e.g., days of good and poor business. When we predict unique phenomena, on the other hand, the uncertainty increases with time.' I should like to suggest that the factors which determine dental arch relationship make up an aggregate in which they may balance out. Many measurements of

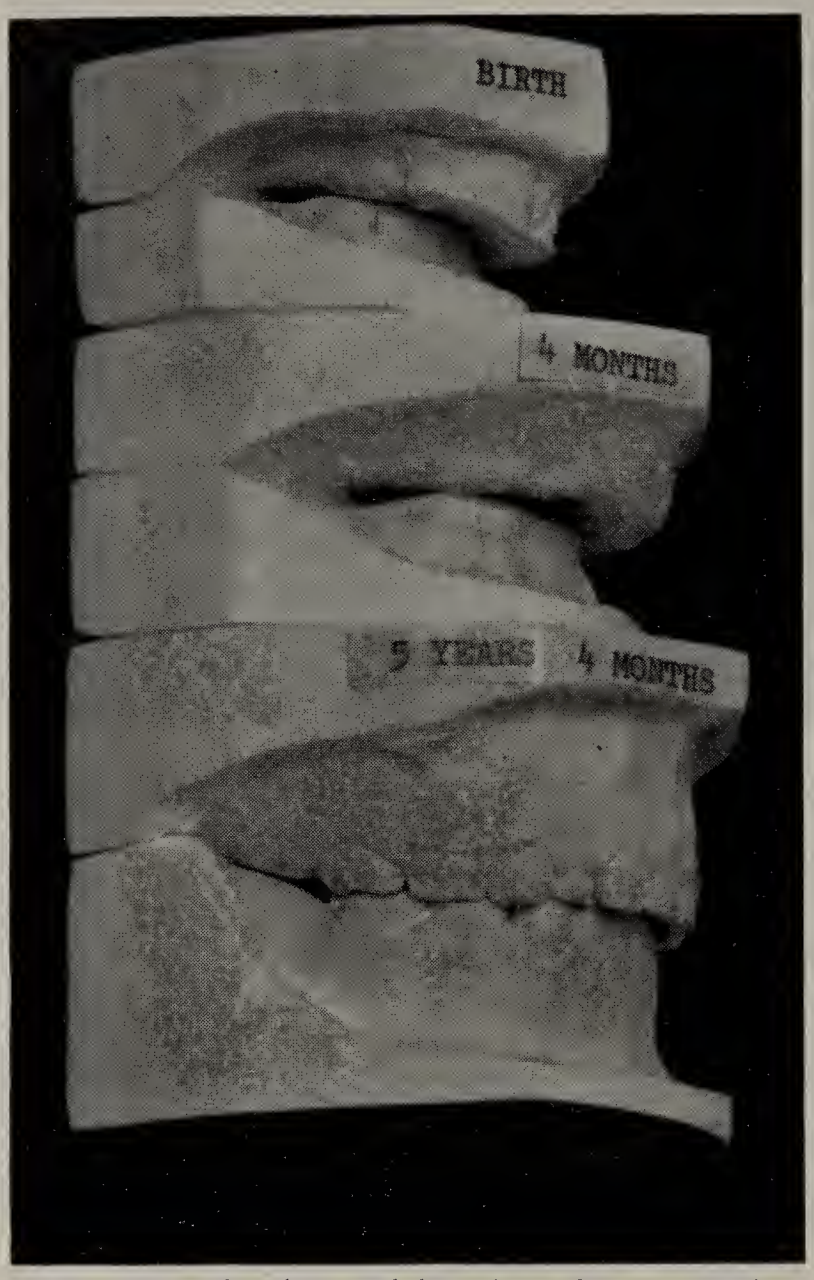


Fig. 11.—Study model series of a case who showed an unusually large overjet at birth. Models were taken at birth, 4 months, and 5 years 4 months and showed a marked reduction of overjet. This might have been greater had it not been for the presence of a supplemental upper lateral incisor.

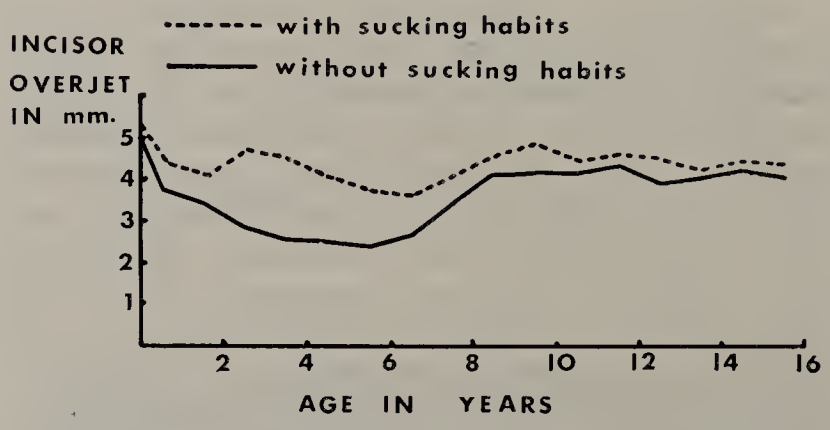


Fig. 12.—Graph to show changes of mean overjet between birth and $15\frac{1}{2}$ years in samples of children with and without sucking habits.



Fig. 13.—Models of a case to show how pre-normal occlusion of the deciduous incisors is found before eruption of canines.

Table II.—Correlation Coefficients for Overjet between $15\frac{1}{2}$ Years and Representative Stages of Development*

Age (years)	Correlation Coefficient	
	Whole Sample	No Sucking Habits
Birth	0·16	0·27
$3\frac{1}{2}$	0·43	0·65
$5\frac{1}{2}$	0·55	0·61
$9\frac{1}{2}$	0·85	0·92
$12\frac{1}{2}$	0·93	0·97

* Based on the records of 49 cases from whom no permanent teeth had been lost. Twenty-six of the 49 had no sucking habit after the age of 3 years.

the facial bones, on the other hand, are difficult to predict, behaving more like unique phenomena.

A number of workers have pointed out that the function of cusps in the human dentition is probably to guide the teeth to their correct relationship as they erupt, after which they should be worn down by attrition. It has been found that as cusps of deciduous molars come

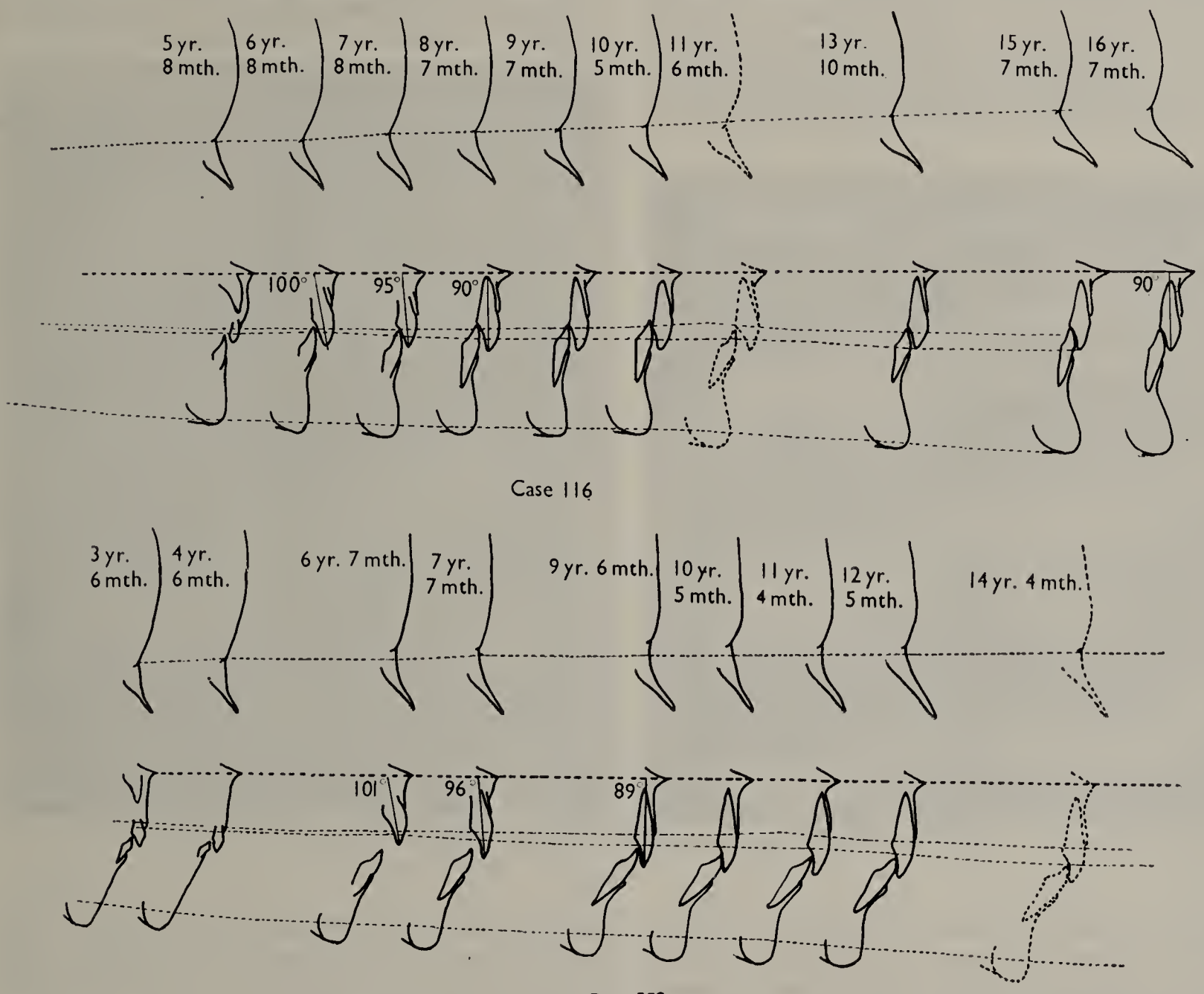


Fig. 14.—A, Serial profile cephalometric tracings of 2 Class II, division 2, cases showing changes of incisor inclination and relationship with age. The interrupted line indicates a period of active treatment. B, Profile tracings showing the relationship of incisors to the lip line.

into occlusion with opposing teeth, they often initiate new proprioceptive sensations which contribute to a change of occlusal relation. This is probably protective, but may cause spontaneous changes of occlusion as more molars erupt. Subsequent attrition may allow a return to centric relation. Such changes of occlusion may either increase or decrease the degree of postnormality. It is also possible for similar changes to occur as a result of tooth movement produced by sucking habits. In a previous paper (Leighton, 1966) a case was shown in which a sucking habit caused distal displacement of the mandible by narrowing of the upper intercanine width. Later a cross-bite was adopted and the mandible once more moved forward to a normal anteroposterior relation.

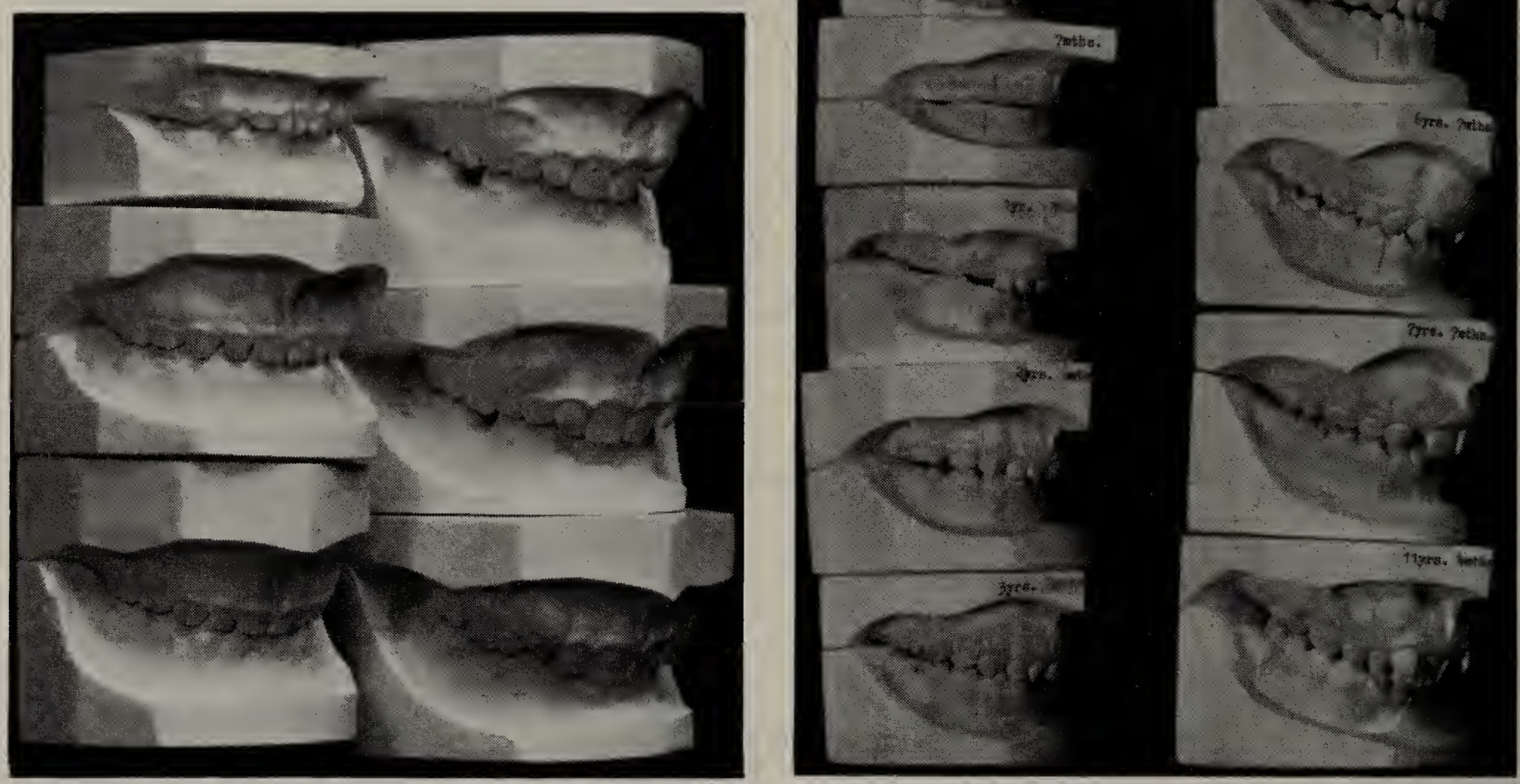


Fig. 15.—Serial study models of the cases shown in *Fig.* 14.

Provided the contribution made by sucking habits is allowed for and mandibular displacements are not overlooked, it is possible to make fairly accurate predictions of anteroposterior relation by the age of 6 years. Prenormal occlusion, on the other hand, is usually evident by the time deciduous incisors begin to erupt, that is, during the first year. A case is shown which demonstrates the very early appearance of a prenormal incisor relationship (*Fig.* 13). It will be noted that this relationship was established before eruption of the canines, although it may appear to the inexperienced that the inclined planes of the deciduous canines at the age of 3 years have played an important part in causing the prenormal occlusion.

During the discussion of a paper by Nicol to this Society in 1955, it was remarked by Pringle that it would be interesting to examine a Class II, division 2 case in the deciduous dentition. It appeared at that time that no one present could recall having identified a Class II, division 2 case before eruption of the permanent incisors. For this reason 2 cases are included (*Figs.* 14, 15). In the first, lingual inclination of the deciduous incisors increased through toddlerhood. The incisor overjet was increased when the permanent incisors erupted, but slowly diminished again during the next 2 years. The incisor overbite was large throughout development from the age when the deciduous incisors erupted. The second case had only an average incisor overbite in the deciduous dentition, and at first showed little lingual inclination of incisors. It was not until the upper lateral incisors erupted that the occlusion took on the typical appearance of a Class II, division 2 malocclusion.

In a previous paper to this Society (Leighton, 1966) the significance of crossbites and buccal occlusion in the deciduous dentition was discussed at some length, and will therefore be omitted from this paper.

ALINEMENT OF TEETH

One of the most characteristic features of malocclusion in this country is the presence of crowding. Although this is probably made worse by indiscriminate extraction of deciduous teeth, there is little doubt that there is usually an underlying disproportion of size. It has been suggested

by several authors (Tratman, 1950; Murphy, 1964; Begg, 1965; Dickson, 1969) that considerably more space could be made available if we were to suffer the same amount of attrition as our more hardy ancestors. In spite of the desirability of massive attrition, it is unlikely that it would be acceptable as a remedy for crowding. Extraction of teeth is a more popular and more certain form of therapy. It is here that the art of timing treatment is likely to be of most benefit, and a knowledge of the accuracy and the limitations of prediction is valuable. This aspect of orthodontics is particularly relevant to the work of the general practitioner. It is inevitable that at times extractions will be required as part of general dental treatment. It will therefore be of value to him to be equipped to make a fairly accurate prediction of the degree of crowding to be expected in the permanent dentition, and in addition to forecast the effect of extractions upon the position of remaining teeth. To a large extent crowding is a manifestation of the relation between the size of the teeth and the size of the arch in which they are to be accommodated.

Several authors have examined the degree of correlation between the size of the deciduous teeth and that of the permanent teeth (Moorrees, 1959; Lysell, 1960). Confirmation has been found that correlation of the sum total of all the deciduous teeth of each arch is moderately strong with that of their successors (*Table III*). Because certain teeth are so variable it was felt that correlation between selected teeth of the deciduous dentition and their permanent incisors, canines, and premolars might repay examination. Their variability makes lower incisors and canines especially valueless for predictions, the deciduous molars being the better yardsticks. However, no individual tooth of either arch is better by itself than the sum of all the deciduous teeth. Equally important with the size of the teeth themselves is the size of the arch they are to occupy. Previous authors have attempted to correlate measurements of arch width with the amount of space which may be expected to be available (Stifter, 1958). This must, however, be made difficult by wide variation in the shape of the dental arch. It seems more logical to measure the circumferential length of the dental arch. Thus, the outer periphery of each arch was measured from a point immediately buccal to the distal aspect of the second deciduous molar to a similar point on the opposite side. In the permanent dentition these points correspond to the distal aspect of the second premolars or the mesial aspect of the first permanent molars. Only a modest correlation was found between the peripheral length of the arch of the deciduous teeth and that of their successors, when all cases were considered, regardless of extractions (*Table IV*). On the other hand, segregation of those cases from whom no teeth at all had been extracted showed a much stronger correlation in the deciduous dentition phase.

Spacing of deciduous teeth has for many years been accepted as a desirable phenomenon as it allows accommodation of larger permanent teeth without any very great increase of anterior arch size. If spacing is not established by the time the deciduous dention is completed it is unlikely to appear later. In a previous paper (Leighton, 1969) it was shown how although there was a mean difference of 6 mm. and 2 mm. between the deciduous tooth diameters and those of their

Table III.—Correlation Coefficients of the Sums of the Successional Tooth Diameters with Representative Deciduous Teeth in 103 Cases

Teeth	Correlation Coefficient	
	Upper Teeth	Lower Teeth
Incisors	0·59	0·47
Canines	0·55	0·33
First molars	0·50	0·55
Second molars	0·49	0·59
First and second molars	0·57	0·65
Canines, first, and second molars	0·66	0·63
All deciduous teeth	0·70	0·65

Table IV.—Correlation Coefficients for the Peripheral Length of the Upper and Lower Arches between 15½ Years and Representative Stages of Development

Age (years)	Correlation Coefficient			
	Whole Sample		*No Deciduous Teeth extracted*	
	Upper Arch	Lower Arch	Upper Arch	Lower Arch
3½	0·61	0·78	0·78	0·70
5½	0·64	0·67	0·82	0·79
9½	0·82	0·71	0·88	0·84
12½	0·95	0·93	0·94	0·86

Table V.—Prediction of Crowding in the Lower Arch*

Deciduous Tooth Spacing	*Chances of Later Crowding*
Crowding	10 in 10
No spaces	7 in 10
Less than 3 mm.	5 in 10
3–6 mm.	2 in 10
More than 6 mm.	None

* Based on the longitudinal records of 49 cases.

permanent successors in the upper and lower arches respectively, these figures represent very wide ranges. The amount of spacing cannot afford by itself a very precise indication of the amount of crowding to be expected in the permanent dentition. It was found in a sample of 49 individuals that the total amount of spacing may be used to estimate the probability of later crowding (*Table V*).

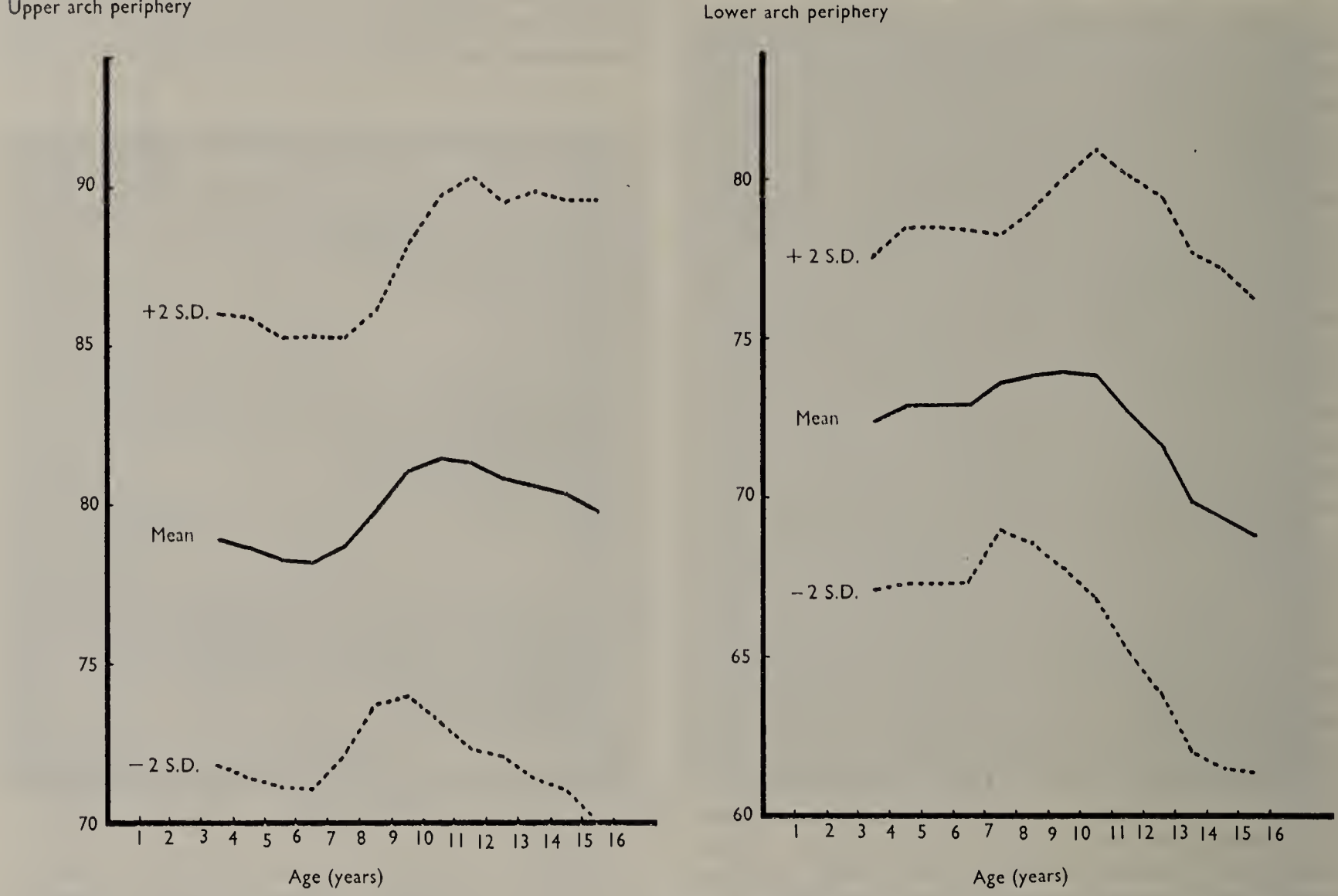
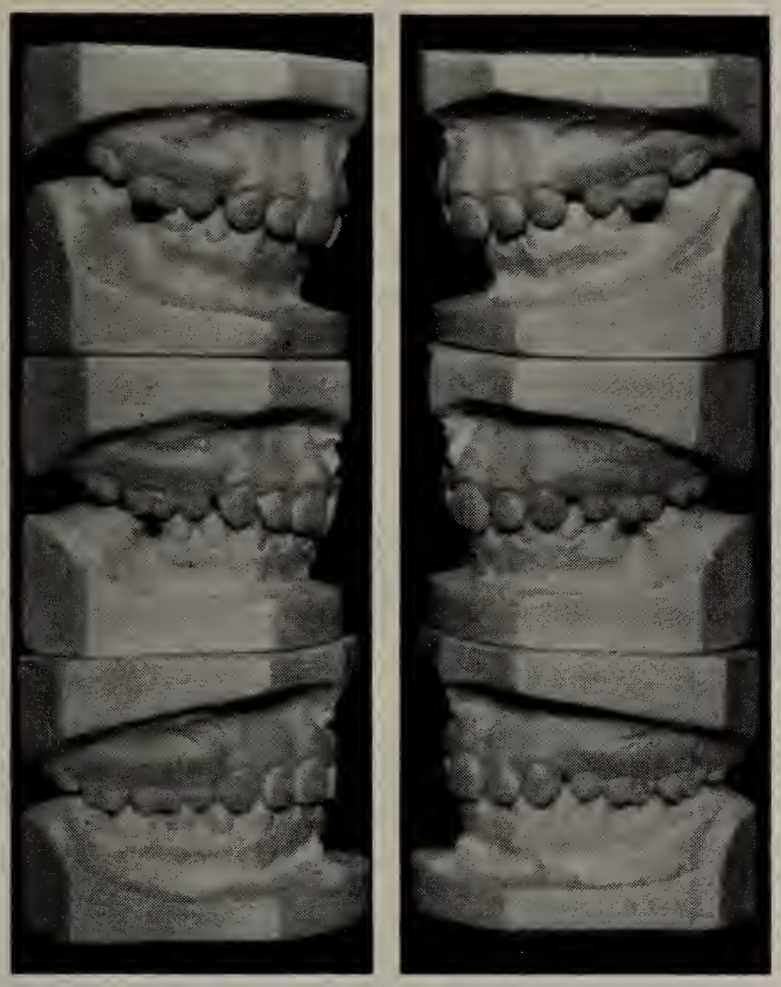


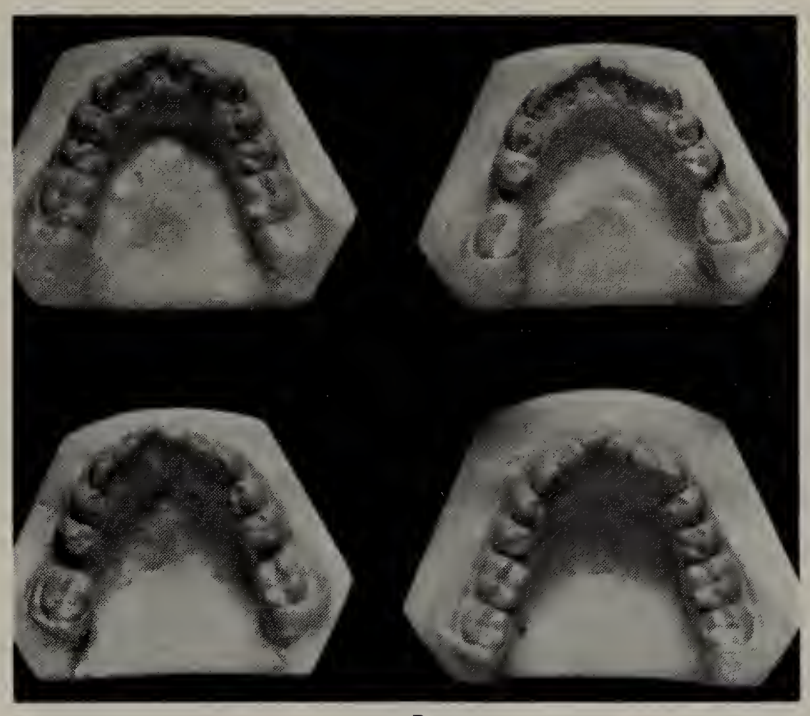
Fig. 16.—Graphs to show changes of mean peripheral length of each arch between $3\frac{1}{2}$ and $15\frac{1}{2}$ years in 19 cases from whom no teeth had been extracted. The extent of individual variation is indicated by the 2 standard deviation range.

Examination of the changes that take place in the peripheral arch length is of considerable interest, and is rather different in each arch. To a large extent these changes may be related to shedding and eruption of teeth (*Fig*. 16). By following the yearly change of mean peripheral length in 19 cases from whom no teeth had been extracted, it was found in the upper arch that an initial decrease of peripheral length during the deciduous dentition phase was associated with closure of molar spaces and reduction of incisor protrusion as sucking habits were abandoned. Between 6 and 10 years an increase of the average length accompanied eruption of permanent incisors. The subsequent slow reduction of length was initially due to replacement of deciduous molars by premolars. It did, however, continue for some time after the premolars were established. By 15 years the mean peripheral length was only slightly larger than it had been at 3 years. The changes that take place in the peripheral length of the lower arch are broadly similar except that no initial decrease of arch length was found. The increase between 6 and 10 years was followed by a substantial decrease whose rate was sustained until at least 15 years of age. This reduction of arch periphery, especially in the lower arch, was mentioned in the discussion of a paper by Pringle (1955) to this Society in which he laid before the Society the long-term results of a number of treated Class II, division 2 cases. During the discussion Chapman suggested that delayed imbrication of lower incisors was so common that it might be considered to be normal. This suggestion has since found wide general support in this country. It seems to provide a strong case for the policy of leaving some spacing at the conclusion of treatment. Failure to do so may permit some imbrication of incisors to develop between the ages of 13 and 16 years.

A case is shown to demonstrate the spontaneous closure of upper and lower spaces following orthodontic treatment involving the extraction of upper first premolars and lower first permanent molars (*Figs*. 17, 18). The upper canines and incisors were retracted and residual spacing was

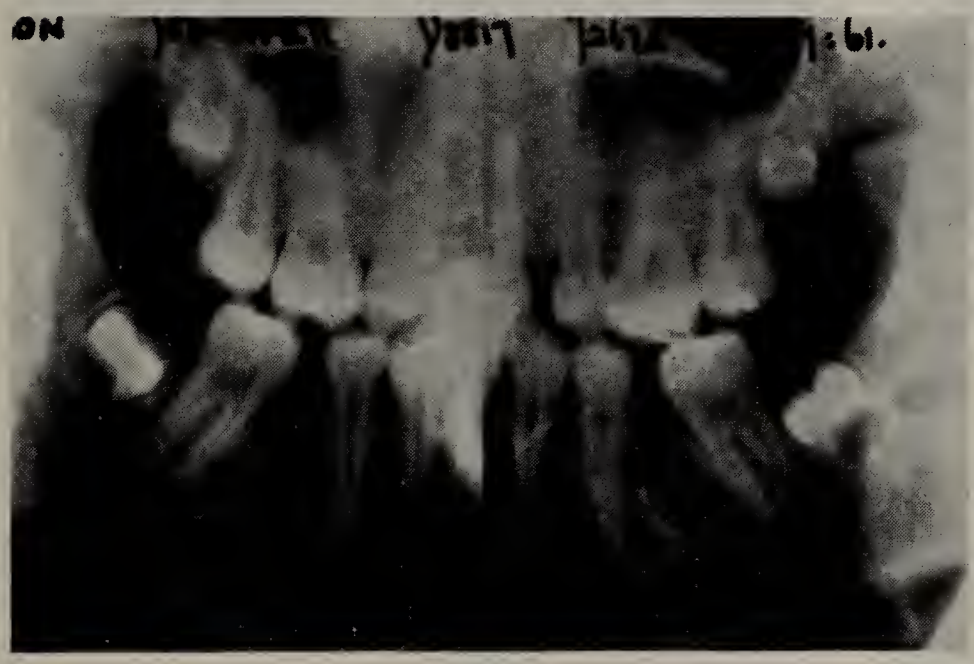


A



B

Fig. 17.—A, Models of a case where the upper first premolars were extracted before retraction of the upper canines and incisors with removable appliances. Later, the lower first permanent molars were extracted. There has been complete spontaneous space closure except for a small space between the upper left canine and the first premolar. B, Models of the same case show the spontaneous closure of the lower spaces during 4 years (*Top left*, 12 years; *top right*, 14 years; *bottom left*, 15 years; *bottom right*, 18 years).





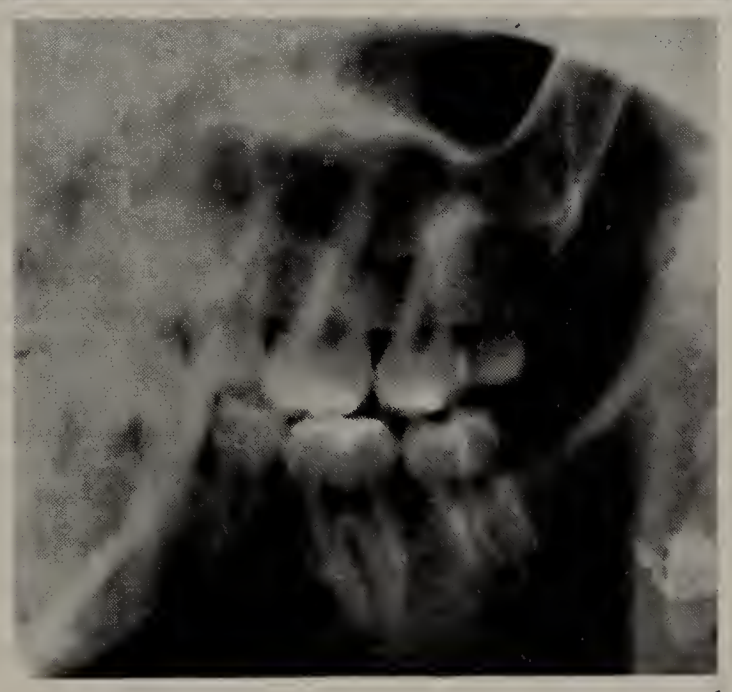


Fig. 18.—Radiographs of the case shown in *Fig.* 17 demonstrate approximation of the roots of the second premolars and the second molars.

left. During the next 4 years the upper molars, the second premolars, and the lower second molars migrated mesially without tilting and closed the spaces. There are, of course, some cases for whom lower spacing might be very dangerous; for example, a Class II, division 2 malocclusion where the overbite is so precarious that even the slightest lingual inclination of the lower incisors would be disastrous.

It is now generally accepted that the extraction of deciduous teeth does not always cause a lasting loss of space for the permanent dentition. This is

nearly always true of cases with generous spacing of the deciduous teeth, but only partly true where there is only a small amount of spacing. It may be a predisposing factor to late imbrication of incisors, as is shown in the case in *Fig.* 19. Lower first deciduous molars were extracted at 7 years but the space was regained when the premolars erupted. Later, however, some imbrication of the incisors appeared.

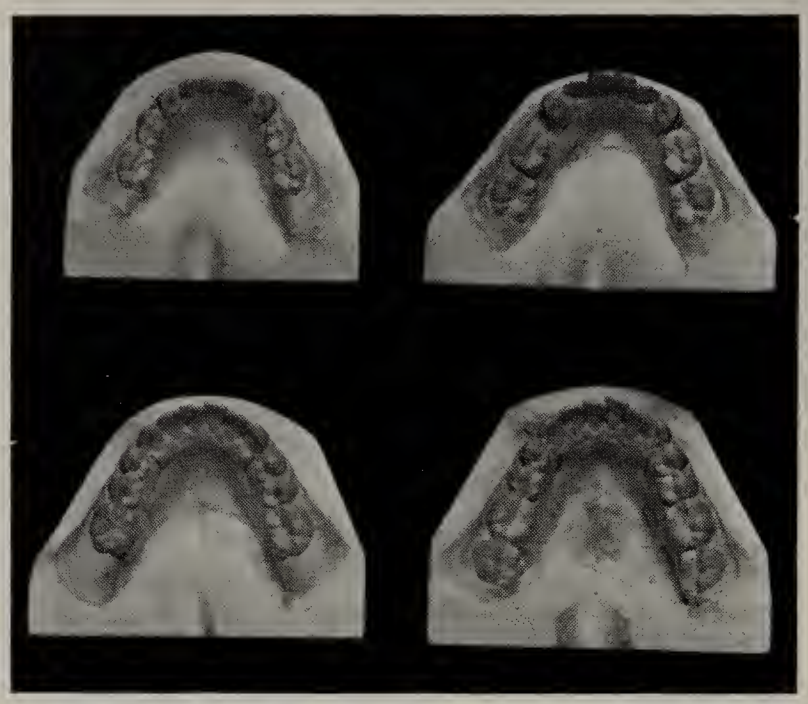


Fig. 19.—Models of a case in which the lower first deciduous molars were extracted. Although the premolars appeared to erupt satisfactorily later, this was followed by some incisor imbrication soon after eruption of the second molars. Models are shown at 5 (top left), 8 (top right), 11 (bottom left), and 14 (bottom right) years.

SUMMARY

It has been the purpose of this paper to draw attention to the value of a sound knowledge of all development affecting tooth occlusion and alinement, and the ability to predict which it will confer. It is only by fostering study along these lines that unnecessary or inappropriate treatment will be eliminated, and the treatment given may often be simplified by careful selection of the age for its administration. I think it very likely that technical advances in the fields of surgery and biophysics may greatly increase the demand for precise and accurate prediction of growth changes. At the moment we are ill equipped to answer such demands.

In everyday practice there are countless predictions which the experienced practitioner makes without being conscious of the process by which they are made. Much of this is based upon past experience. In the field of orthodontics this is, however, obtained only after many years because of the long-term nature of the changes with which we deal. The time has now arrived when it is necessary to attempt to record observations made over a long period of time in such a way that they can be analysed and imparted to other members of the profession for use in making predictions. This was the advice of Northcroft in 1909, advice which has been very largely ignored during the last 60 years. It would be appropriate, therefore, to conclude this paper by quoting the final sentence from Northcroft's Presidential Address, 61 years ago: 'Before bringing these discursive remarks to a close, I would again insist on the necessity of accumulation of facts, for many a pet theory may be rendered untenable by one awkward, little practical fact.'

Acknowledgements

It is never possible to undertake prolonged research without the help of others, particularly when this requires co-operation of patients. Without the continual and loyal support of the children and their parents I should now have only a collection of discontinuous records. To them I owe the greatest debt of all. Nearly as great is my obligation to Mrs. J. Hart whose cheerful persistence has maintained contact with the children so successfully, and to my professional colleagues at King's College Hospital who have suffered considerable inconvenience over the years in the cause of this project.

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THE INTERCHANGEABLE PLASTIC BRACKET

A. C. L. GIBSON, B.D.S., F.D.S., D.D.O., D.Orth., H.D.D.
Ayrshire Hospitals Orthodontic Service, Central Health Clinic, Kilmarnock

INTERCHANGEABLE plastic brackets were first introduced in the United States of America during 1967, but they have not yet been described in the British literature.

The system is basically an attempt to camouflage the hardware of the multiband fixed appliance by the use of broad-based white plastic brackets. These are slotted into stainless-steel receptacles which are welded to all conspicuous bands (*Figs.* 1, 2). This method has the added advantage of permitting brackets to be changed during treatment, while the cemented bands remain in situ.

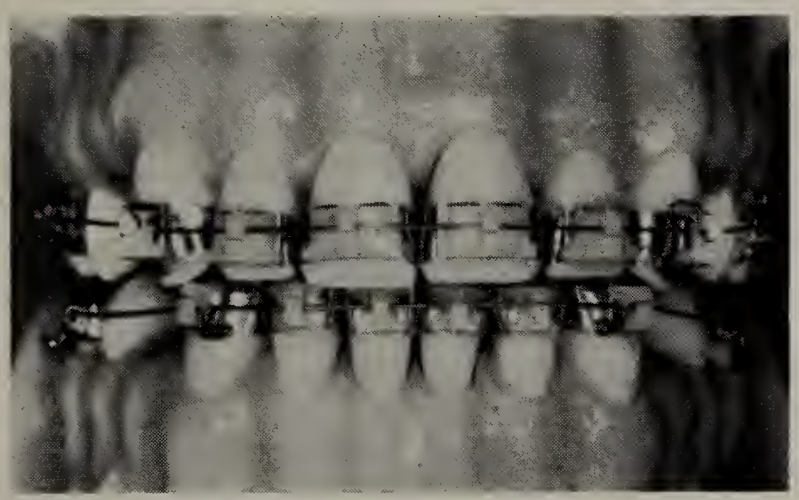


Fig. 1.—Interchangeable plastic brackets with archwires in situ demonstrating the cosmetic improvement over conventional multiband appliances.



Fig. 2.—Interchangeable plastic bracket removed to reveal the arrangement of the welding points in the incisor and canine receptacles.

THE MATERIAL

During the last decade several outstandingly strong thermoplastics have been developed and labelled ' the engineering materials '. Of these the polycarbonates have been found to be ideally suited to use in the mouth, and are strong enough to be fashioned into the delicate shapes required of orthodontic brackets.

THE MECHANISM

As mentioned above this system comprises two components: the receptacle, and the plastic shield and bracket.

The Receptacle (*Fig.* 3)

This is an open-fronted stainless-steel box with overhanging side flanges which retain the plastic component in position. The side flanges are deficient in the occlusal one-third of the box to permit oblique insertion and removal of the interchangeable plastic bracket over the occlusal rim of the box. Once past this rim or clip the plastic bracket cannot accidentally slip out. The occlusal and gingival flanges of the box also are incomplete, having a midline notch for the insertion of either a preliminary ligature, in cases of severe irregularity, or an uprighting auxiliary.

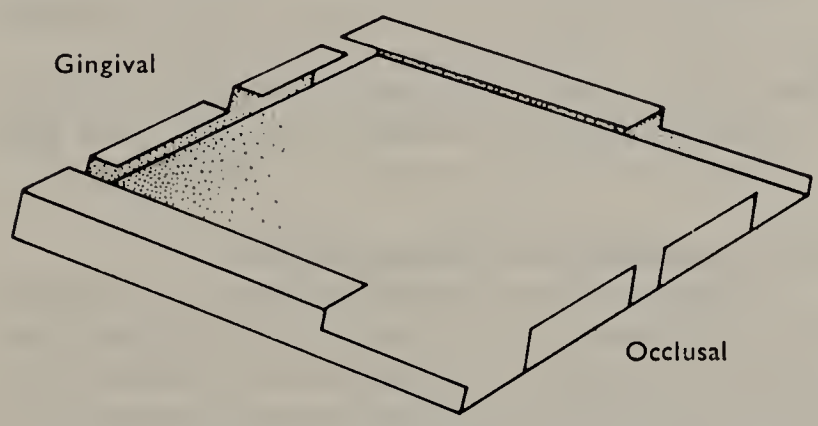


Fig. 3.—The stainless-steel receptacle, with the gingival surface on the left and the occlusal surface on the right. Note the overhanging flanges on all but the occlusal aspects; also the midline notches for insertion of a ligature or uprighting spring.

Presented at the meeting held in Aberdeen on 23 October, 1970.

Both the receptacle and the interchangeable plastic bracket are tapered slightly towards the gingival surface and are curved slightly mesiodistally to conform to the corresponding features of the labial surfaces of the incisor teeth. Complete adaptation to the curved labial surfaces of the canine and the premolar teeth cannot be achieved and this leads to the welding-points

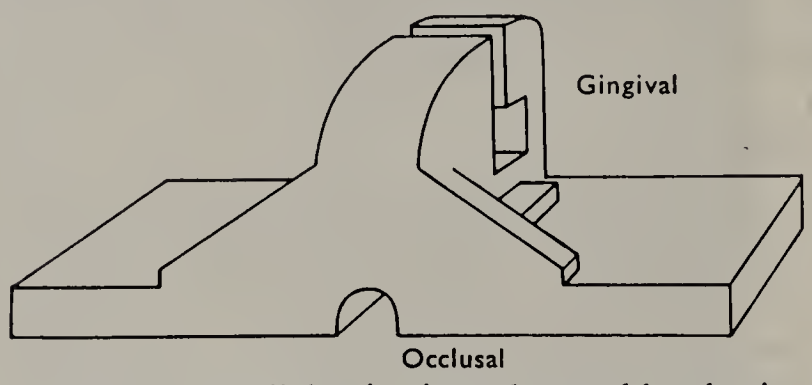


Fig. 4.—The lightwire interchangeable plastic bracket with the occlusal surface on the left. Note the labial slot for the insertion of the archwire and the absence of a lockpin channel; also the vertical slot in the base for the accessory wires.

being confined to the central region of the box. To avoid distortion only linear welding along the long axis of the tooth is advised for curved teeth, whereas widely spaced welding-points are possible in the case of the incisors, giving a stronger union between band and box.

Different sizes of receptacle are available, the choice depending on three factors:—

a. The width of band tape; 3·8 mm. or 3·4 mm.

b. The width of tooth mesiodistally; 4 sizes are obtainable.

c. The convexity of the tooth; limited welding area restricts size for reasons of strength.

The sizes commonly used are ' wide ' for $\underline{1|1}$, ' medium ' for $\underline{2|2}$, ' narrow ' for $\underline{3|3}$ and premolars, and ' extra-narrow ' for $\overline{321|123}$.

The Interchangeable Plastic Bracket

For descriptive purposes the plastic component can be divided into two parts, although these are, in fact, inseparable: the therapeutic portion, i.e., the actual bracket, and the cosmetic portion, i.e., the specially enlarged base, which acts as a camouflaging shield, obscuring the maximum possible amount of band and receptacle. The polycarbonate used has a translucent, tooth-like appearance and, once the bracket is fitted, only the flanges of the receptacle remain uncovered.

Both ' lightwire ' and ' edgewise ' brackets are obtainable, it being possible to substitute the different types of bracket without the trouble and expense of a complete rebanding operation. This is primarily of advantage to operators practising a hybrid technique, e.g., completing Begg cases with a few months on edgewise arches.

Edgewise brackets are available with two sizes of slot: 0·017 in. × 0·028 in. and 0·022 in. × 0·028 in. ' Large ' and ' Medium ' bases carry Siamese brackets. ' Narrow ' and ' Extra-narrow ' bear single brackets.

Lightwire brackets differ considerably from those of Begg (*Fig.* 4). The bracket is closed in design, above and below, since no pinning is



Fig. 5.—Method of removing the interchangeable plastic bracket.

required, the archwire being sprung through a narrow labial slot into a larger channel, where the fit is loose enough to prevent binding. The fitting surface has a vertical groove along the midline of the base coinciding with the corresponding notches in the receptacle for the insertion of a ligature or root-paralleling spring.

INSERTION AND REMOVAL OF BRACKETS

A. Seating the Bracket

1. Identify the narrower tapered end of the base of the bracket.
2. Grasp one occlusal corner with a fine haemostat or Howe pliers.
3. Engage the opposite gingival corner in the appropriate side flange.
4. Flex the base slightly to engage the other gingival corner.
5. Complete insertion with a band-pusher until past the occlusal clip.

B. Removing the Bracket (*Fig.* 5).

1. The base being inaccessible to instrumentation, apply gentle traction to the bracket itself.
2. Grasp the bracket occlusogingivally close to the base with a blunt pair of ligature cutters.
3. Gently rotate the occlusal end of the bracket over the lip of the receptacle.
4. The remainder of the base should now slip easily from the receptacle.

SUMMARY OF THE ADVANTAGES AND THE DISADVANTAGES

Advantages

1. Cosmetic improvement.
2. The archwires snap into the brackets.
3. No ligatures or pins are required to retain the archwires.

4. The archwires are easily removed for adjustment.
5. There is a reduction in chair time.
6. The brackets may be changed without disturbing the existing bands.

Disadvantages

1. The combined receptacle and bracket is considerably bulkier than a conventional metal bracket.
2. The receptacle may tear from the band in traumatic situations, especially on convex teeth.
3. The appliance is unsuitable in ' close-bite ' cases unless combined with a bite-raising appliance.
4. Wide separation of the welding points is not possible on convex teeth.
5. Plastic brackets may become distorted by occlusion or instrumentation.
6. The looped archwires may be deformed by the snap method of insertion and removal.
7. No eyelets are available for control of rotations.

AN INVESTIGATION INTO THE PREVALENCE OF MOLAR CROSSBITE AND SOME ASSOCIATED AETIOLOGICAL CONDITIONS

A. J. W. DAY, B.D.S., F.D.S., D.Orth.
Consultant Orthodontist, Birmingham Dental Hospital

T. D. FOSTER, M.D.S., F.D.S., D.Orth.
Professor of Children's Dentistry and Orthodontics, Birmingham Dental School

THE condition of molar crossbite affects some 16 per cent of orthodontic patients but has attracted little attention regarding either aetiology or treatment.

McCall (1944), in the study of the occlusion of 775 children between the ages of 2 and 11 years, records 5 per cent of posterior crossbite. He states, however, that where more than one type of malocclusion was found the type having the greatest functional significance was recorded.

Rix (1946), in 22 cases of tooth-apart swallowing, recorded that 7 or 32 per cent had molar crossbite. Leighton (1953) in a survey of 2700 children stated that crossbite in the molar region is frequently associated with sucking habits. Gardiner (1955) in a survey of Sheffield schoolchildren puts the frequency at 16 per cent. Munro (1956) in a paper on digit-sucking said that in some cases of digit-sucking unilateral or bilateral crossbite may occur. Wood (1962) suggested that posterior crossbite may be caused by prolonged retention of primary teeth, crowding, premature loss of primary teeth, palatal cleft, thumb-sucking, and arch deficiencies, and says that the condition tends to relapse when treated.

In a more recent publication Kutin and Hawes (1969), in two samples of children between the ages of 3 and 9 years, showed 8 per cent with posterior crossbite and came to the conclusion that molar crossbite was not self-correcting, a crossbite in the primary dentition being followed by a similar condition in the mixed dentition, but that if treated in the primary dentition it led to a normal bite in the mixed dentition.

Hanson, Barnard, and Case (1970) found 12 per cent of lingual crossbite in a sample of 214 pre-school children. They found that this condition was 'functionally associated with tongue thrust with meaningful consistency' and suggested that the narrow upper arch 'possibly promotes thrusting by forcing a narrowing of the tongue, thereby increasing its length'.

In view of the apparent high prevalence of molar crossbite, an investigation was undertaken to enquire into the origin of the condition and to assess its prevalence in a population sample and in an orthodontic clinic.

SOURCES OF MATERIAL

The material for this investigation was derived from the examination of 2752 patients referred for advice or treatment to the Orthodontic Department of the Birmingham Dental Hospital between December, 1966, and September, 1969, and from a survey of 965 Shropshire schoolchildren aged 11–12 years, conducted in the Spring, 1970.

The Dental Hospital material is not representative of a true sample of the population nor is it truly similar to the average orthodontic practice as it contains a number of unusual types of malocclusion. It was, therefore, decided to eliminate from the material 20 patients with cleft palate, 45 non-Caucasians, 244 who were over the age of 15, 1 patient with facial deformity, and 1 with severe partial anodontia. The 244 patients over the age of 15 included a number with severe Class III occlusion and cases of lateral open bite, etc., many of which had already had some orthodontic treatment elsewhere which had not proved entirely satisfactory. The original sample of 2752 which included 468 cases with molar crossbite was thus reduced to 2441 including a total of 400 cases of molar crossbite. It is these 400 patients which form the main subject matter for this paper and from which the

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analysis of molar crossbite has been obtained. The data from the survey of Shropshire schoolchildren has been included for comparison with a normal population.

EXAMINATION OF THE MATERIAL

The examination of the material was carried out by one or other of the authors of this paper in order to insure as far as possible uniformity of criteria. In every case an orthodontic assessment was made and all the data obtained were recorded on a punch card for ease of processing at a later date.

The criteria for inclusion in the molar crossbite category was that the upper permanent or primary molar teeth were in linguo-occlusion. In practice this meant the upper first permanent molar was in crossbite in most cases. In some few cases the upper first permanent molar had been extracted so the second permanent or primary molar was used for assessment. In no case has linguo-occlusion of the upper premolar teeth been included as the position of these teeth was considered to be too unreliable, influenced as it is by early loss of primary teeth and crowding. It will be noted that the term ' molar crossbite ' as used in this paper is not synonymous with ' posterior crossbite ' which is more broadly based and includes buccal as well as lingual occlusion of the upper posterior teeth.

CLASSIFICATION OF MOLAR CROSSBITE IN RELATION TO POSSIBLE CAUSES

Consideration of the possible causes of molar crossbite led to an investigation under four headings but two of these, namely, sucking habits and tooth-apart swallowing, can be grouped together as soft-tissue behaviour. The categories used are, therefore (1) skeletal, (2) dental, and (3) soft tissue.

Skeletal causes are those in which there is disharmony of the craniofacial skeleton. For the purpose of this paper these were examined only so far as there was a skeletal Class III relationship of the jaws.

Dental causes are those in which a tooth such as an instanding or misplaced upper incisor may cause deviation on closure owing to cuspal interference. The criterion for this feature was that one or two upper incisors should occlude lingually to the lower incisors. If more than two incisors were instanding this was recorded as reverse overjet.

Soft-tissue causes are those where there is some deviation from normal behaviour such as tooth-apart swallowing or sucking habits. The criterion for inclusion as a digit-sucker was that the subject should still have been actively indulging this habit at the age of 5 years.

These three classes do not necessarily include every cause of molar crossbite neither are they mutually exclusive. For example, some skeletal Class III cases sucked digits or had tooth-apart swallowing. The three classes do, however, cover at least 90 per cent of the subjects with molar crossbite (*Fig.* 1).

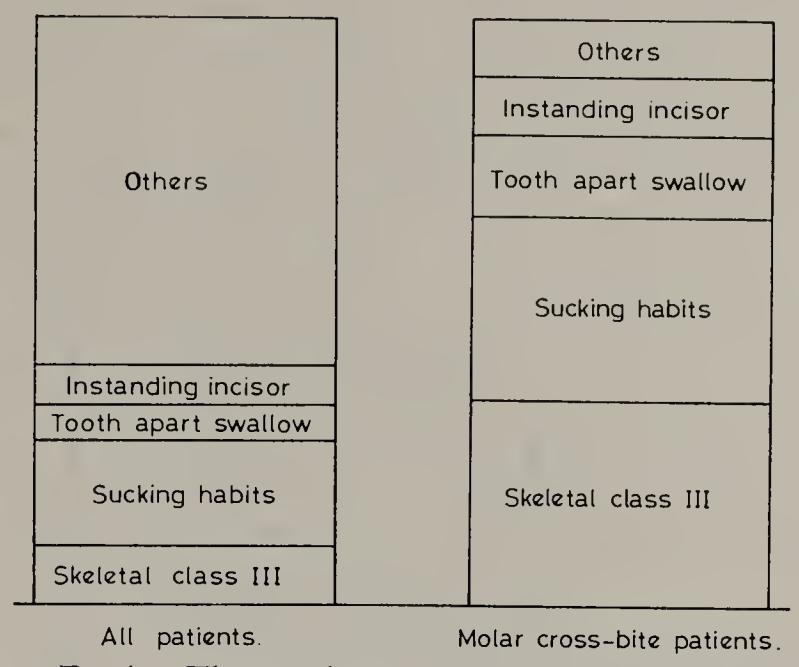


Fig. 1.—The relative proportions of the features investigated in the total sample and in the molar crossbite group. Where more than one of the features, such as digit-sucking, tooth-apart swallowing, or instanding incisor, were present in a patient the necessary adjustments have been made to preserve the correct proportions.

STATISTICAL ANALYSIS

The results of the assessment of the 2441 patients are shown in *Tables I* and *II*. It can be seen from *Table I* that the skeletal Class III subjects showed a very high proportion of unilateral and bilateral crossbites, and statistical analysis showed a highly significant difference between skeletal Class III and other subjects for unilateral crossbite ($\chi^2=100{\cdot}7092$, $P<0{\cdot}001$) and bilateral crossbite ($\chi^2=412{\cdot}3804$, $P<0{\cdot}001$).

In order to assess the significance of the relationship between molar crossbite and the other features which were investigated, viz., instanding incisors, thumb-sucking, and atypical tooth-apart swallowing, a statistical analysis was carried out using the χ^2 test, first on the total sample and then excluding the skeletal Class III subjects, From the figures in *Table I*, the following results were obtained:—

1. *Total Sample*

a. Instanding incisors—unilateral crossbite: 59 patients; $\chi^2=56{\cdot}9267$, d.f.$=1$, $P<0{\cdot}001$.

b. Instanding incisors—bilateral crossbite: 21 patients; $\chi^2=7{\cdot}6563$, d.f.$=1$, $P<0{\cdot}01$.

c. Thumb-sucking—unilateral crossbite: 102 patients; $\chi^2=82{\cdot}4419$, d.f.$=1$, $P<0{\cdot}001$.

d. Thumb-sucking—bilateral crossbite: 47 patients; $\chi^2=26{\cdot}8451$, d.f.$=1$, $P=0{\cdot}001$.

e. Abnormal tooth-apart swallow—unilateral crossbite: 48 patients; $\chi^2=77{\cdot}4571$, d.f.$=1$, $P<0{\cdot}001$.

Table I.—Assessment of New Patients at an Orthodontic Clinic

Crossbite	Total Sample		Skeletal Class I		Skeletal Class II		Skeletal Class III		Instanding Incisor		Sucking Habit		Tooth-apart Swallow	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
No crossbite	2041	83·6	716	86·2	1206	89·3	119	45·7	165	67·3	329	68·9	94	55·6
Unilateral crossbite	258	10·6	85	10·2	112	8·3	61	23·5	59	24·1	102	21·3	48	28·4
Bilateral crossbite	142	5·8	30	3·6	32	2·4	80	30·8	21	8·6	47	9·8	27	16·0
Total	2441		831		1350		260		245		478		169	

Table II.—Assessment of New Crossbite Cases at an Orthodontic Clinic

Crossbite	Total Crossbite Sample		Skeletal Class I		Skeletal Class II		Skeletal Class III		Instanding Incisor		Sucking Habit		Tooth-apart Swallow	
	No.	Per cent*	No.	Per cent*	No.	Per cent*	No.	Per cent*	No.	Per cent*	No.	Per cent*	No.	Per cent*
Unilateral crossbite	258	64·5	85	21·2	112	28·0	61	15·2	59	14·7	102	25·5	49	12·0
Bilateral crossbite	142	35·5	30	7·5	32	8·0	80	20·0	21	5·2	47	11·7	27	6·7
Total	400	100	115	28·7	144	36·0	141	35·2	80	19·9	149	37·2	75	18·7

*The percentage occurrence of each feature in the total crossbite sample.

f. Abnormal tooth-apart swallow—bilateral crossbite: 27 patients; $\chi^3=52{\cdot}6439$, d.f.$=1$, $P<0{\cdot}001$.

2. *Excluding Skeletal Class III Subjects*

a. Instanding incisors—unilateral crossbite: 39 patients; $\chi^2=36{\cdot}6626$, d.f.$=1$, $P<0{\cdot}001$.

b. Instanding incisors—bilateral crossbite: 7 patients; $\chi^2=1{\cdot}4510$, d.f.$=1$, $P>0{\cdot}2$.

c. Thumb-sucking—unilateral crossbite: 99 patients $\chi^2=125{\cdot}9596$, d.f.$=1$, $P<0{\cdot}001$.

d. Thumb-sucking—bilateral crossbite: 39 patients; $\chi^2=85{\cdot}9412$, d.f.$=1$, $P<0{\cdot}001$.

e. Abnormal tooth-apart swallow—unilateral crossbite: 47 patients; $\chi^2=106{\cdot}0293$, d.f.$=1$, $P<0{\cdot}001$.

f. Abnormal tooth-apart swallow—bilateral crossbite: 17 patients; $\chi^2=59{\cdot}2557$, d.f.$=1$, $P<0{\cdot}001$.

Thus, with one exception, the relationship between molar crossbite and the features studied proved significant at a high level of probability. It can be said, therefore, that there is evidence that unilateral molar crossbite is related to skeletal Class III, instanding incisors, thumb-sucking, and abnormal tooth-apart swallow, while bilateral molar crossbite is related to skeletal Class III, thumb-sucking, and abnormal tooth-apart swallow. The exception is the relationship between instanding incisors and bilateral crossbite, which failed to reach statistical significance when the skeletal Class III subjects were omitted. This is, of course, to be expected. The instanding incisor would tend to cause an initial contact and a deviation in the path of mandibular closure leading to unilateral rather than bilateral crossbite.

THE AETIOLOGICAL FACTORS IN MOLAR CROSSBITE

Skeletal Class III

In the skeletal Class III group there were 141 patients with molar crossbite or 35 per cent of the total crossbite sample. At first sight it might appear that the disadvantageous relationship of the upper and lower jaws would be sufficient cause to make the dental arches occlude with a molar crossbite. If, as we believe, the crowns of the teeth are in equilibrium with the forces acting upon them, then we can expect the soft tissues to attempt to correct the deficiencies in the jaw relationship. In fact, this does appear to happen in a number of cases, and in the sample under review only 54 per cent of the skeletal Class III cases had a molar crossbite. In the Shropshire survey 56 per cent of the skeletal Class III cases had a molar crossbite.

There are, of course, a number of different types which can be included in the skeletal Class III, some with a high Frankfurt-mandibular-plane angle, some with a large mandible, and some with a very small maxilla. Where the disharmony is great, the soft tissues are unable to compensate sufficiently to prevent a crossbite developing and a very small maxilla may not have the growth potential to respond to the efforts of the soft tissues. Some cases have other factors such as tooth-apart swallowing and sucking habits which contribute to the crossbite position. Finally, the position of the tongue at rest in the Class III case may be the deciding factor in determining the presence of molar crossbite as in a number of patients the tongue at rest is low in the mouth and may not offer much support to the upper teeth.

Ballard (1959), in a series of lateral skull radiographs, showed that the tongue posture varied as the maxillary-mandibular-plane angle varies. The higher the angle, the lower the dorsum of the tongue in relation to the hard and soft palates. In other words, the abnormality of the craniofacial skeleton which caused the Class III relationship may also predispose to a disharmony of the lingual and perioral musculature.

Hopkin (1963) concluded that the upper arch width is not dependent on the level of the tongue at rest, which he says is not surprising as it is primarily dependent on the size of the base from which the alveolar element springs which is genetically determined. Cookson (1967) using lateral skull radiographs found no significant difference in tongue position when comparing high and low maxillary-mandibular-plane angles or when comparing patients who ' had or did not have a crossbite in the buccal occlusion '. However, it is not the level of the dorsum of the tongue as revealed in lateral skull radiographs that is likely to be the determining factor in causing molar crossbite but the level at which the tongue seals against the molar teeth. If it seals below the occlusal level of the upper molars a crossbite could be the result.

As has been stated earlier some of the skeletal Class III cases also showed abnormalities of soft-tissue behaviour and some could have been included in the dental group with instanding incisors. However, it was felt that the Class III relationship was the dominant factor and so no Class III cases have been considered in the dental or soft-tissue groups.

Dental

Cuspal interference due to instanding incisor teeth was present in 46 or 11 per cent of the crossbite patients, excluding those in the skeletal Class III group. This was the smallest group under investigation and included 10 patients who had abnormalities of soft-tissue behaviour which may have been of more significance than the instanding incisor tooth. In the Shropshire survey 8 cases or 8·5 per cent of the total with molar crossbite had an instanding incisor.

All but 4 patients had unilateral crossbite as might be expected where cuspal interference may cause a deviation in the path of closure. The 4

which had bilateral crossbite had small crowded maxillae and may more properly belong to the skeletal class of molar crossbite but could not be included as skeletal Class III because of the normal anteroposterior jaw relationship.

Although statistically it can be shown that there is a significant relationship between the instanding upper incisor tooth and a molar crossbite this does not necessarily imply cause and effect. The instanding incisor tooth is most commonly caused by crowding and it is possible that other more general conditions may be responsible for both instanding incisors and molar crossbite in a number of patients.

of the opinion that the dental arches whether normal or abnormal were in a position that was in balance in soft-tissue morphology and behaviour.

The practice of orthodontics is based on the knowledge that if a small pressure is exerted continuously on the crown of a tooth, then the tooth will move if free to do so, and that in the normal mouth many forces act upon the crowns of the teeth which must, therefore, be considered to be in a state of equilibrium with these forces.

In a study of molar crossbite it is essential to examine this paradoxical situation and to try to resolve the differences of opinion because, as will be shown later, the soft-tissue environment of the

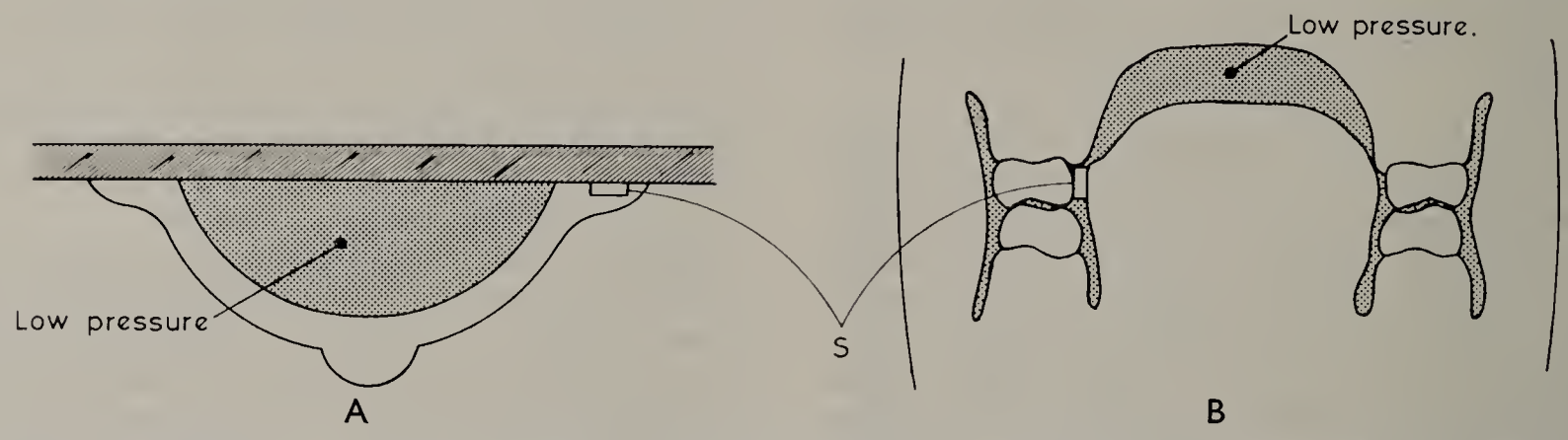


Fig. 2.—Diagram to illustrate the effects of suction on pressure measurement (A) on a suction disk and (B) within the mouth. The pressure sensor placed at S will register positive pressure as a result of the low pressure in the enclosed space.

Soft-tissue Behaviour

Ever since Rix (1946) focused attention on tooth-apart swallowing, orthodontists have been concerned to relate certain types of malocclusion to this kind of soft-tissue behaviour. Whilst recognizing the association between the malocclusions and this behaviour, there have been doubts that tooth-apart swallowing alone could be the cause of some of the malocclusions. In recent years it has become fashionable to attribute more and more to hereditary factors and less and less to the soft-tissue environment although, of course, muscle activity is to a large extent genetically determined.

Pressure measurements on teeth by Friel (1926), Stevens (1956), Hopkin and McEwen (1957), Kydd (1957), and Sims (1958) have shown that the pressures exerted by the lingual musculature exceed those of the perioral musculature often by as much as four times.

Winders (1956) using strain-gauges attached to the lingual and buccal aspects of the teeth came to the conclusion: ' investigation indicates that there is an apparent imbalance of muscular forces acting on the dentition between the lingual and buccal sides with the greater force being exerted by the tongue '. Dixon (1959) concluded: ' Experimental and clinical evidence cannot support the view that the dentition is in a state of balance with the soft tissues '.

On the other hand, Brodie (1954), Ballard (1955), Hovell (1956), and many others are firmly

crowns of the molar teeth appears to play a large part in the production of some molar crossbites.

No doubt some of the difficulties in which we find ourselves are due to inadequate knowledge of the physical forces exerted by the actions of the soft tissues which surround the teeth. This applies particularly where negative air pressure is produced during deglutition or other activity such as digit- or lip-sucking.

If a rubber suction cup clinging to a sheet of glass is considered (*Fig.* 2A), a strain-gauge placed between the rim of the cup and the glass would demonstrate that the rubber was pushing against the glass or vice versa with a pressure equal to the difference between the atmospheric pressure outside and the reduced air pressure inside the suction cup. No movement takes place because this is static pressure. If the rubber suction cup is now pushed or pulled, the strain-gauge will register more or less pressure but still a positive pressure. Comparing this situation with what occurs in the mouth (*Fig.* 2B) it will be seen that a strain-gauge placed between the tongue and lingual side of a tooth will show a positive pressure but will take no account of the air pressure between the tongue and the palate which may be much less than atmospheric pressure. The conditions of the suction cup and in the mouth are, of course, not exactly the same because the tongue is a very versatile body of muscle which can exert pressure in any part by virtue of the intrinsic muscles and can exert

positive or negative air pressures by means of the extrinsic muscles.

THE ROLE OF NEGATIVE INTRA-ORAL AIR PRESSURE IN THE AETIOLOGY OF CROSSBITE

The relationship between molar crossbite and digit-sucking and tooth-apart swallowing habits leads to the thought that the soft-tissue behaviour could be producing molar crossbite by inducing a negative air pressure in the mouth. The pattern of air pressure changes in the mouth, in certain types of oromuscular behaviour was, therefore, studied using a method previously described (Day and Foster, 1970).

Briefly, the intra-oral part of the apparatus consists of a suitable orthodontic band fitted to a premolar or primary molar on the bucal aspect of which is attached two 0·5 mm. SS. tubes, one of which leads to the buccal side of the molar teeth and one to the palatal vault to have its open end near the centre of the hard palate. A polythene tube, 0·55 mm. in diameter, connects the intra-oral appliance to a pressure transducer which is connected to an amplifier system. The output is recorded on an ultra-violet light recorder.

Using this apparatus it was possible to obtain precise measurements of the magnitude and duration of negative air pressures in the mouth, and from these some idea of the underlying pattern of behaviour of which tooth-apart swallowing and digit-sucking are the outward visible signs.

The digit-suckers in the molar crossbite sample were closely studied and compared with some who had no molar crossbite.

Air-pressure measurements were made in the palatal vault and on the buccal aspects of the upper molar teeth. These measurements were usually the same in the molar crossbite sample which was in distinct contrast to those without molar crossbite where the pressure measurement on the buccal aspect of the molar teeth showed little or no change whilst high negative pressures were recorded in the palatal vault.

During digit-sucking very severe negative pressures were recorded and some of the youngest subjects gave the most dramatic recordings, often in excess of 100 units*, whilst actively sucking their fingers or thumb. It would appear, therefore, that the position of the periphery of the tongue whilst producing the suction in the mouth may be an important factor in the production of molar crossbite. The case illustrated (*Fig.* 3A) shows continuous negative pressure whilst thumb-sucking which usually is in excess of 30 units and does exceed 100 units at point X, where the trace goes off the scale. A tracing from the same child at rest (*Fig.* 3B) exhibits negative pressure of between 30 and 50 units over a period of 1 minute.

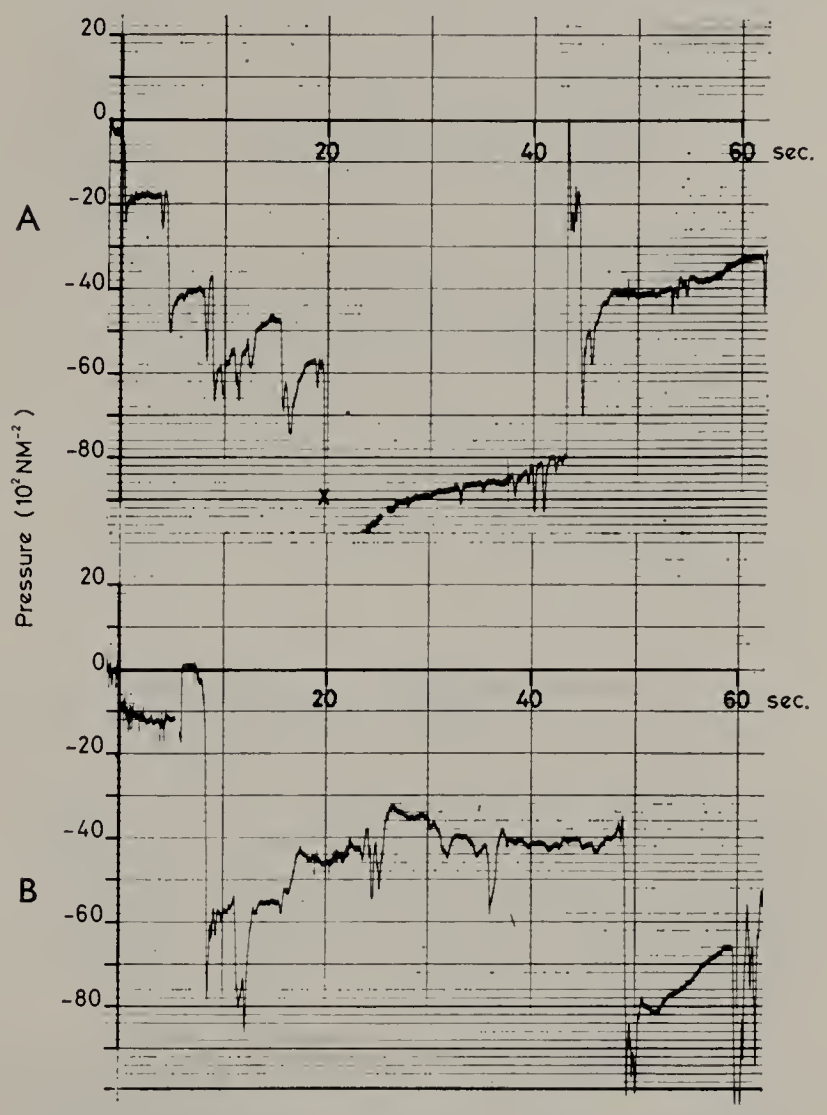


Fig. 3.—Traces showing variations in intra-oral air pressure in a child with a thumb-sucking habit. A, Sucking the thumb. B, Not sucking the thumb but still producing prolonged negative pressure.

Another recording (*Fig.* 4A) shows the trace of a child finger-sucking. Here there is as much positive pressure as negative which demonstrates that the child is not sucking the finger but idly playing with it. At point Y the patient is swallowing. A trace from the same child (*Fig.* 4B) not sucking her finger demonstrates considerable sucking activity with negative pressure at times in excess of 50 units. This is not a sustained negative pressure but an illustration that the sucking activity associated with the digit-sucking is persisting for a while though there is no real sucking when the digit is in the mouth. These 2 cases of digit sucking have been chosen to illustrate this paper because they demonstrate rather well some of the more important aspects of sucking habits and the associated malocclusions. First, the placing of a digit in the mouth may only be part of a sucking activity which may persist even

*The units of pressure referred to are of the order of $10^2 N m.^{-2}$ which is approximately equivalent to g. per cm^2. *N* (Newton) is the unit of force in the new International System of Units (SI) and is that force which gives an acceleration of 1 m. per sec. to a body of 1 kg. mass. This means that a mass of 1 kg. under the influence of gravity exerts a force 9·8 *N*. These units are fully described in ' The International System (S.I.) Units ', British Standard 3763.

when the digit is not in the mouth. Secondly, the placing of a digit in the mouth does not necessarily denote sucking activity and, indeed, in certain cases there may be less sucking with the digit in the mouth than when it is removed. Thirdly, both the patients illustrated (*Figs.* 3, 4) had Class II dental base relationships where the digit sucking had exaggerated the overjet and

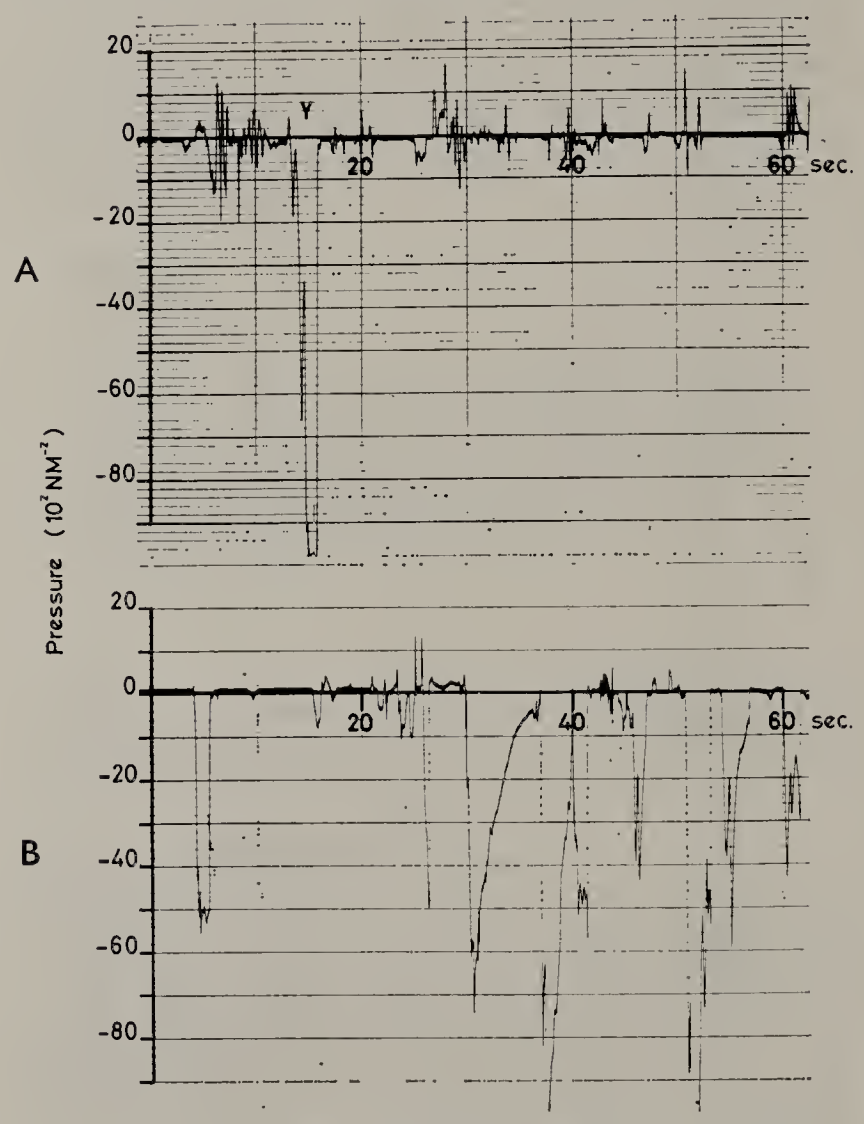


Fig. 4.—Traces of variations in intra-oral air pressure in a child with a finger-sucking habit. A, With the finger in the mouth, showing very little sucking activity. At point Y the patient swallowed. B, Not sucking the finger but showing considerable rhythmic sucking activity.

produced an incomplete overbite which made a tongue to lower lip oral seal essential. Thus, the digit-sucking may produce a postural activity which is akin to tooth-apart swallowing. In the sample 18 digit-suckers also had tooth-apart swallowing behaviour.

As a result of numerous tracings obtained from digit-suckers who were still sucking and from patients who had ceased sucking for a year or so, it became obvious that the sucking activity may persist for some time after the so-called digit-sucking had ceased. It was for this reason that the criterion for the digit-sucking was that they should be actively engaged in this habit at the age of 5 years, the assumption being that even if the habit stopped abruptly at this age the sucking activity at rest would persist till after the eruption of the first permanent molars.

Lawes (1950) expresses the opinion that malocclusions caused by thumb-sucking ' tend to correct themselves if the habit is broken by the age of five years but do not tend to correct themselves if the habit persists beyond this age '.

Sucking habits were associated with 37·2 per cent of the molar crossbite cases including those on skeletal Class III bases. In the Shropshire

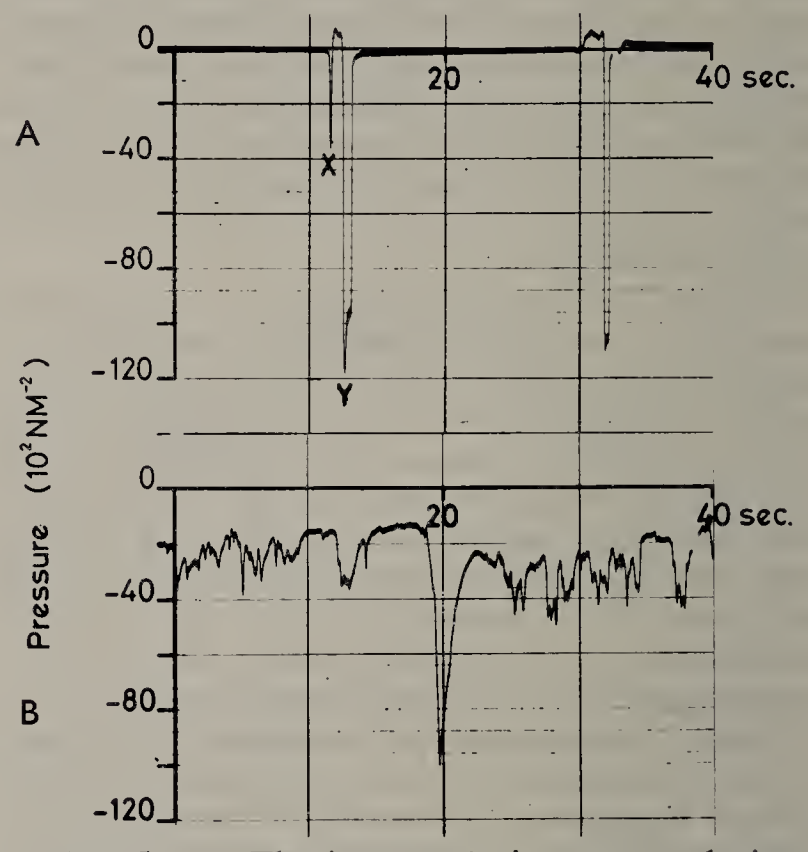


Fig. 5.—A, The intra-oral air pressure during normal swallowing behaviour. X shows the collecting phase and Y the swallowing phase. B, The intra-oral air pressure during tooth-apart swallowing. There is an absence of a collecting phase, possibly due to the constant level of negative pressure.

survey 40 per cent of the molar crossbite cases had associated sucking habits.

The study of the patients with tooth-apart-swallowing showed considerable variations in behaviour which merit much more study. For the purposes of this paper it is only possible to discuss those aspects of the behaviour which differ from normal swallowing and which may have a close connexion with the feature of molar cross-bite.

Ballard (1955) suggested that there were probably several differing types of tooth-apart swallowing and described two: those of endogenous origin and those whose habit posture has been reflexly established to produce an anterior oral seal where there is an incompetent lip posture associated with an increased overjet.

Again Ballard (1957) states: ' Open lip posture results in a habit pattern of activity during swallowing to produce an anterior oral seal, sometimes it is just an increase in the contraction of muscles but frequently the tip of the tongue also plays a part by coming between the teeth to contact the lower lip.'

This investigation confirms these views and as has already been observed, digit-suckers who have produced an exaggerated overjet and incomplete overbite have a tongue to lower lip anterior oral seal. Furthermore, in these cases, if the anterior oral seal is maintained at rest then this is always accompanied by a degree of negative pressure in the mouth as any positive pressure would destroy the seal. Sometimes this negative pressure can be quite severe.

Of the 75 patients with tooth-apart swallowing in the crossbite sample, all except 1 had an incomplete overbite or incompetent lips or both these features. Twenty-one also had sucking habits such as digit-, dummy-, or lip-sucking and all made contact between the tip of the tongue and the lower lip on swallowing.

In any type of swallowing a certain amount of suction in the mouth is required. If the fluid to be swallowed is deposited on the dorsum of the tongue as in breast-feeding or whilst drinking from a cup or through a straw the amount of suction required is relatively small. If, however, fluid such as emulsified food is already in the mouth, some in the buccal vestibule and some under the tongue, it can only be collected efficiently if considerably more suction is produced to drive the liquid out of the various parts of the mouth and to collect it on the dorsum of the tongue to be swallowed. In normal circumstances this is achieved by lowering the tongue after establishing an anterior and posterior oral seal, but in tooth-apart swallowing the mandible is also lowered and the tongue may lose contact with the upper buccal teeth.

Pressure recordings were made of a number of individuals with normal occlusions and normal swallowing behaviour. Many variations were found in different individuals but the basic behaviour was usually the same. The trace in *Fig.* 5A shows that the sucking activity necessary to swallow liquids is in two phases. At X the fluid is collected on the dorsum of the tongue by creating considerable negative pressure (40 units), and this is followed at Y by even more suction as the liquid is swallowed (120 units). These two phases may be so close together as to appear a single sucking action and occasionally the negative pressure in the collecting phase is greater than in the swallowing phase.

The tooth-apart-swallowing cases showed much more variation in behaviour but basically there were two differences from the normal behaviour, the most important being the maintenance of a significant level of negative pressure in the mouth at rest and absence of the collecting phase before swallowing takes place. The actual level of negative pressure during the final phase of deglutition does not differ from that in the normal individual (*Fig.* 5B). Some of the cases examined showed a rhythmic sucking activity very similar to that seen in some of the digit-suckers when not actively engaged in sucking a thumb or finger (*Fig.* 6A).

In the molar crossbite sample 18·7 per cent showed tooth-apart swallowing behaviour. In the Shropshire survey 27 per cent of the molar crossbite cases had tooth-apart swallowing.

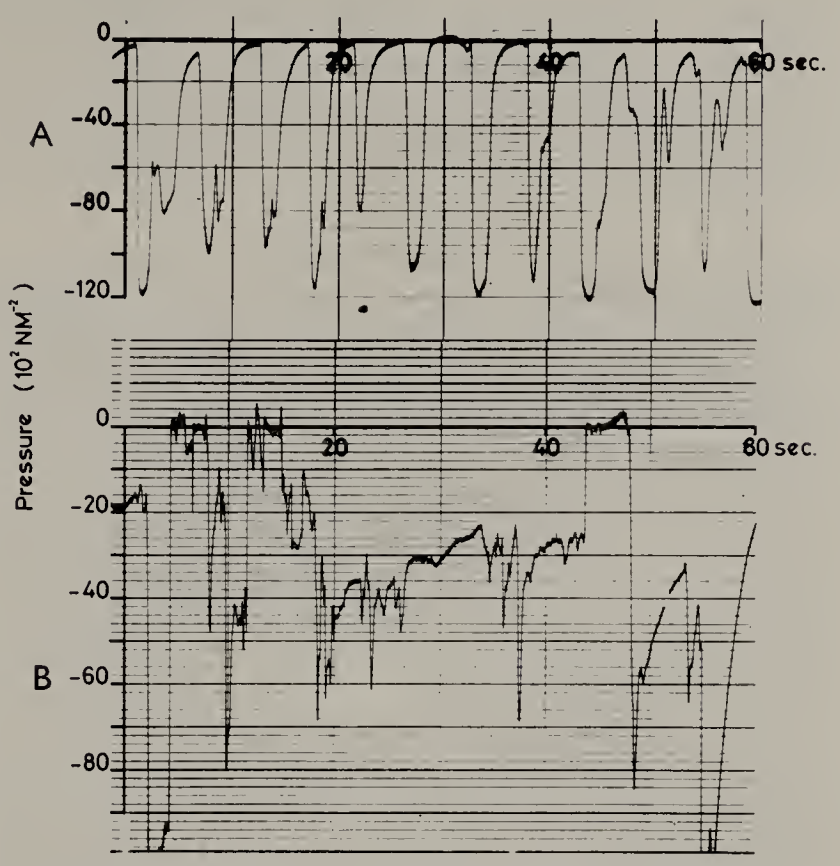


Fig. 6.—A, Trace of intra-oral air pressure of a subject with tooth-apart swallowing behaviour, showing rhythmic sucking activity. B, Trace of intra-oral air pressure of a subject with a molar crossbite of unknown aetiology. The fairly high level of negative pressure can be readily seen.

CROSSBITE CASES OF UNKNOWN AETIOLOGY

The first examination of the patients with molar crossbite showed that 87 per cent were associated with one or more of the features already described. The remaining 13 per cent were then re-examined in case any feature had been overlooked which might account for the crossbite. Thirteen patients did not attend for the re-examination but the 38 who did attend were all tested for negative pressure in the mouth. Ten of these patients showed a sustained negative pressure of more than 15 units whilst relaxing in an armchair. Seven of these who had a Class I occlusion have been included in the sucking-habit group whilst 3 who had a Class II occlusion with increased overjet have been included in the tooth-apart swallowing group. The trace obtained from 1 of these is shown (*Fig.* 6B).

Of the remainder, 6 no longer had a molar crossbite, having apparently spontaneously corrected following the cessation of some habit or correction of cuspal interference, or no longer had their first permanent molars. Twenty-two patients showed no apparent cause for their crossbite and tests for negative pressure in the

mouth did not reach a high enough level to justify their inclusion in the soft-tissue group. Most of these patients also had other faults in their occlusion: 2 had lateral open bite, 2 had missing upper lateral incisors, 1 appeared to have a maldevelopment of one side of the maxilla, and in 1 case the crossbite was caused by a buccally displaced lower molar. Several appeared to have small maxillae with a low rest position of the tongue but were not skeletal Class III although they should properly be included in the skeletal group.

CONCLUSIONS

The investigation shows that molar crossbite occurs in about 12·6 per cent of the population and somewhat more frequently, 16 per cent, in an orthodontic sample.

A small number, 11 per cent, of molar crossbites were associated with cuspal interference such as occurs with lingually placed upper incisors. These were nearly all unilateral as might be expected where there is interference with the path of closure.

Skeletal Class III relationship is associated with 35 per cent of molar crossbite cases and may be the major aetiological factor in some cases. In many cases there are other factors involved owing to the necessity for soft-tissue behaviour to adapt to an unfavourable skeletal pattern. Thus, there may be a low tongue position with a high Frankfurt-mandibular-plane angle or some difficulty in maintaining an anterior oral seal because of the reversed overjet.

Digit-sucking and tooth-apart swallowing behaviour are associated with 50 per cent of molar crossbites and form the largest group, but these observed patterns of behaviour are only the outward visible indications of a sucking activity which persists at times when no habit activity is in evidence.

There seems little doubt that sucking activity accompanied as it is by a high level of negative pressure in the mouth for quite long periods of time may cause some narrowing of the upper arch which will lead to the establishment of a molar crossbite. The deciding factor is likely to be the position of the tongue in relation to the molar teeth. Also digit-sucking and tooth-apart swallowing behaviour lead to the formation of an increased overjet and incomplete overbite which will tend to perpetuate abnormal tongue and lip posture at rest because of the difficulty in maintaining an anterior oral seal.

In the treatment of molar crossbite it is essential to ascertain with some degree of certainty the aetiological factors involved but this can be very difficult where soft-tissue behaviour is involved. A knowledge of the forces involved in the sucking activity may be most helpful because if these are very great there is little hope of successful treatment, but if the activity has subsided to the level of a physiological doodle then the outcome is more hopeful.

Where the molar crossbite is associated with digit-sucking and the consequent adaptive behaviour it should be possible to restore normal occlusion once the sucking activity has been brought under control and the overjet and overbite are restored to normal limits.

Where the molar crossbite is associated with tooth-apart swallowing it is much more difficult to make an assessment, but even in such cases where there is a large overjet there is hope that the sucking activity will subside when the overjet has been corrected. Intra-oral air pressure readings before and after the reduction of the overjet would enable the orthodontist to obtain a clearer indication of the possibility of successfully treating the crossbite.

Acknowledgements

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SPACE CLOSURE FOLLOWING LOSS OF LOWER FIRST PREMOLARS

A. COOKSON, B.D.S., F.D.S., D.Orth. R.C.S.

Dental Department, Good Hope Hospital, Sutton Coldfield

INTRODUCTION

THE extraction of teeth forms an integral part of the majority of courses of orthodontic treatment carried out in this country. Following extractions it is generally acknowledged that spaces tend to close. The tooth most commonly extracted is the first premolar (Hooper, 1966), and in many cases sufficient spontaneous improvement occurs following the loss of these teeth in the lower jaw to obviate the need for further appliance therapy. It would appear, however, on perusing the literature that very little work has been done to try to assess the rate and degree of such space closure following loss of lower first premolars in otherwise untreated lower arches. It was therefore decided to carry out an investigation to assess this, and to try and correlate such space closure as occurred with any possibly relevant aetiological factors, such as the degree of crowding, the skeletal or soft-tissue patterning, and the presence or absence of third molars.

REVIEW OF THE LITERATURE

Many workers have shown a correlation between relief of crowding and extractions in various parts of the arch. Reduction in the prevalence of lower incisor crowding following extractions further back in the arch has been demonstrated by Tulley (1962), McEwen (1964), and Cryer (1965) in studies of different groups of children. It has also been established that the frequency of lower third molar impaction is reduced by the loss of teeth anterior to them, Björk, Jensen, and Palling (1956) and Faubian (1968) demonstrated this in two different studies on the prevalence of impacted lower third molars. However, the only work which is directly concerned with the effects of the loss of lower first premolars *per se* and which is immediately relevant to this project would appear to be that of Mills (1964, 1967, 1970), who carried out an assessment of lower incisor position following the loss of lower first premolars in otherwise untreated lower arches. He studied the effects of extraction on lateral skull X-rays of 35 children, compared with a control of 23 children of the same age-group, and showed that the average position of the lower incisors labiolingually is virtually unaltered following lower premolar extraction. He suggested that the 'keystone' effect of the teeth is negligible but that the zone of muscular balance is all important. He felt that even the slight lingual movement which occurred might be explained by the forward movement of the B point during growth and the resultant minute retroclination of the incisors as they were carried forward, slightly out of a position of muscular balance.

This investigation is complementary to that carried out by Dr. Mills in as much as the results of the loss of lower first premolars has been viewed from an occlusal rather than a lateral viewpoint. His findings and the resultant assumption of the stability of lower incisors labiolingually are therefore fundamental to the relevance of measurements carried out by myself.

Table I.—CONSTITUTION OF THE GROUP (±S.D.)

Number in group	118
Mean age at first impression	10·3 yr. (±2)
Range of ages at first impression	5 yr. 11 mth.–15 yr. 10 mth.
Mean age at second impression	16·2 yr. (±2·4)
Ranges of ages at second impression	9 yr. 8 mth.–21 yr.
Mean age at time of extractions	11·4 yr. (±1·5)
Mean time between extractions and second impressions	4·9 yr. (±1·9)

METHOD

In this investigation 130 patients attending for routine orthodontic treatment at the Royal Victoria Hospital, Bournemouth, had impressions taken for study models at their initial visit. They all had lower first premolars extracted during the course of treatment but no lower arch appliance therapy at all. They were recalled following the completion of treatment and further impressions were taken (*Table I*). Measurements

Presented at the meeting held on 14 December, 1970.

were then made on the study models obtained from these impressions and an initial check was carried out for the constancy of the measurements; those made on 30 of the models were repeated after a few weeks. Despite the greatest care being taken it was found that the reproducibility of the measurements was not as great as

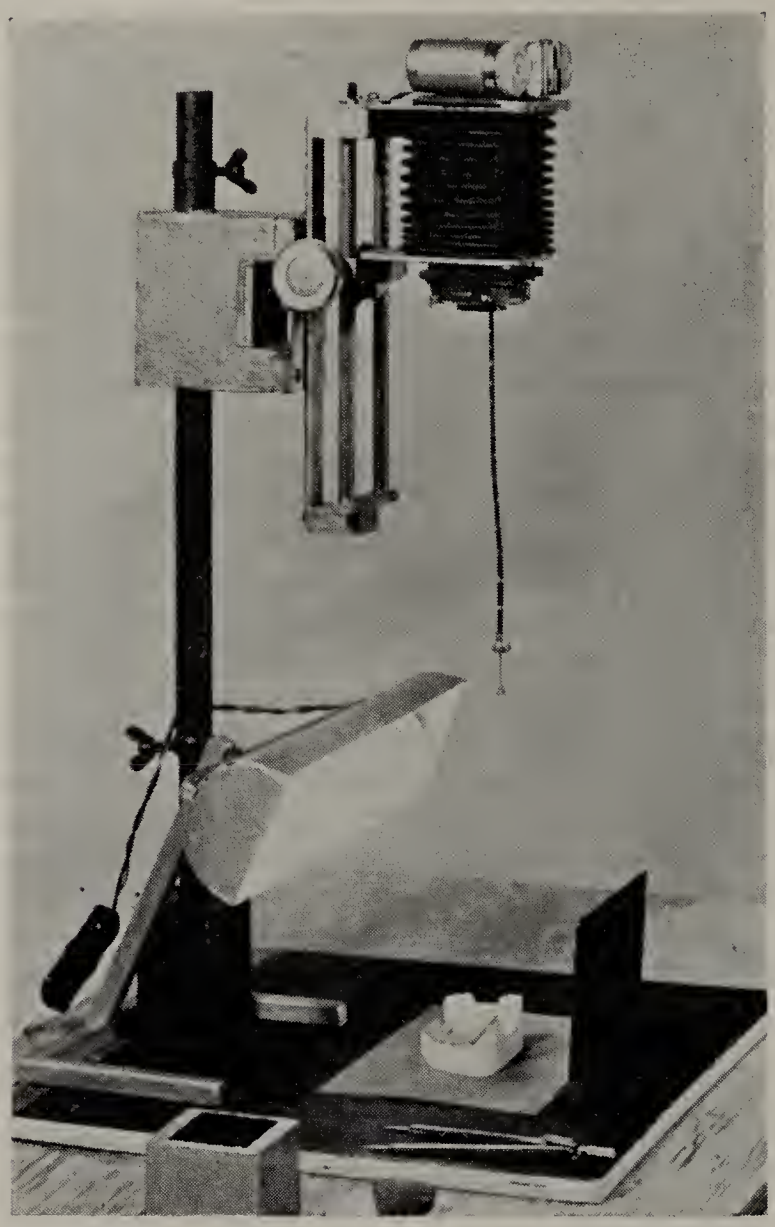


Fig. 1.—The camera set-up used in this investigation.

one would desire and it seemed possible that a photographic method of recording model dimensions might produce more reliable results. A method was then evolved using photographs taken under standard conditions of lighting and position and with the image of a fine grid superimposed on the picture, so that direct readings could be taken from the photograph of distances at the occlusal surface of the model. The grid was produced by taking a photograph of high quality graph paper and scaling it down to the predetermined requisite scale. This grid was situated in the back of the camera nearly in contact with the film surface, that is, virtually at the focal plane of the camera lens.

A long focal length lens was used to reduce errors due to perspective as far as possible—in this case the focal length was 105 mm. It was felt that previous variations in measurements on the models might have been due to failure to place the points of the dividers accurately on the curving surfaces of tooth cusps and that the use of a lens of this nature, plus standardized lighting, would eliminate errors due to the vertical discrepancies.

The grid used within the camera was a one-third linear reduction and this enabled even the

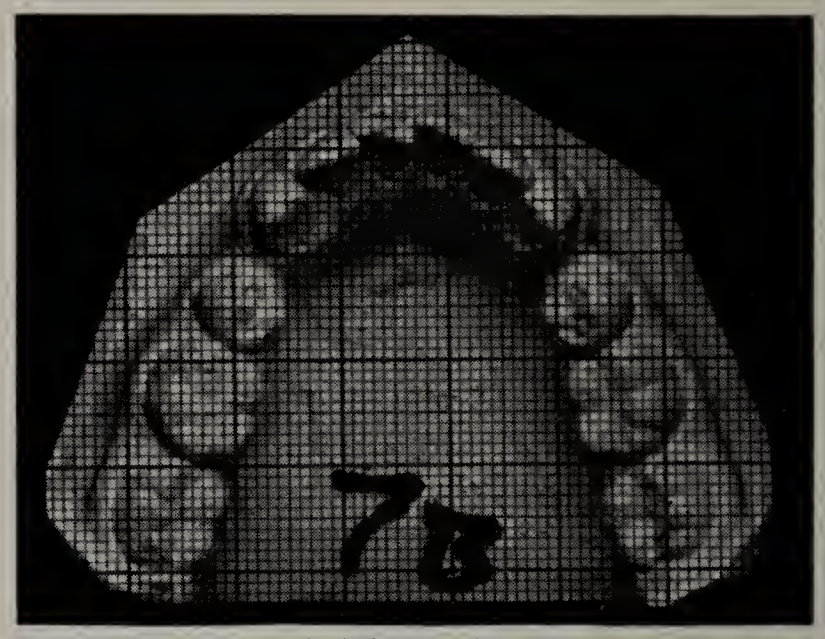


Fig. 2.—A typical slide produced by the camera.

largest models to be accommodated within the picture-area of a 35-mm. frame.

In order to determine the correct distance of the camera lens from the occlusal plane of the model, the camera could be focused in the normal way using a large aperture. However, this distance could also be calculated using the formula $U=\left(\frac{1}{M}+1\right)r$, where M is the linear reduction required, f is the focal length of the lens, and U the lens to object distance. A distance of 42 cm. was used in this case.

The models were trimmed so that the occlusal plane was horizontal and the illumination was by means of an 8-inch, 60-watt, tungsten filament strip-light positioned above and in front of the models. The models were then photographed by the method described.

The images lost very little of their quality despite being photographed through a grid, and the resultant millimetre network superimposed over the entire picture area made it possible to measure down to 0·5 mm. with an acceptable degree of accuracy. A series of 30 sets of measurements were then compared for constancy, and as these were found to be reliable this method was adopted for the whole investigation.

It is worth digressing at this point to mention that this method can also be applied to photographing models in occlusion from a lateral and an anteroposterior viewpoint as well as from the occlusal view used here. All these views can have a similar grid superimposed to enable actual measurements to be made at the tooth surfaces. This could then possibly provide an adequate method of recording the information normally

obtained from reference models and thereby avoid the problems of their storage in large numbers.

Fig. 1 shows a photograph of the original apparatus used in this investigation. It is hoped to be able to produce commercially a more sophisticated apparatus which has been demonstrated elsewhere. *Fig.* 2 shows a typical photograph of a model taken through the grid.

From the photographs measurements were taken to indicate circumferential arch length

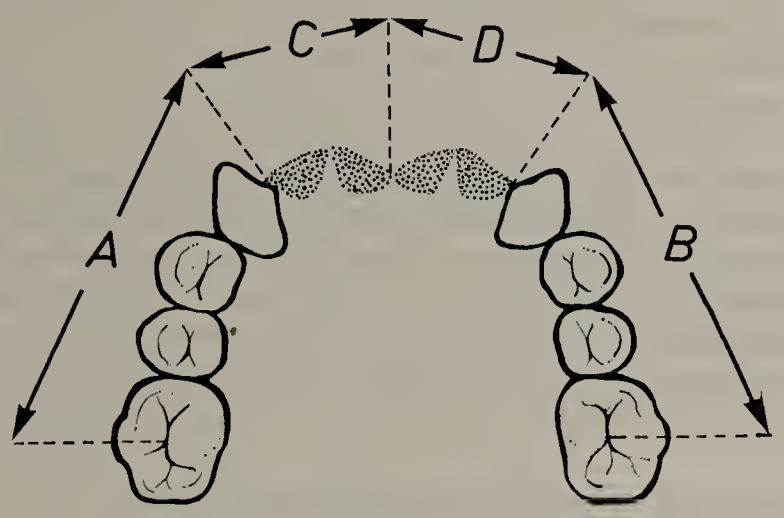


Fig. 3.—Arch measurements. *See* text for definition of the measurements.

(arch perimeter). Points were chosen on the first permanent molars which were able to be clearly located on both sets of models. In all measurements but particularly in the case of the first molars it is impossible to use the same point in every case. The important fact is that one is concerned with establishing any changes in circumferential arch length and comparing these. Therefore, as long as the point chosen is exactly reproducible on both slides of the models of any one case, this will give the desired information.

The arch perimeter was measured in sections by a method similar to that originally described by Lundstrom (1949) except that two of his points of reference were omitted (*Fig.* 3). The distances measured were as follows: A was from a point on the lower left first permanent molar to the distal corner of the left mandibular lateral incisor. B was the same measurement on the right side. C was from the distal corner of the lower left lateral incisor to the mesial corner of the lower left central incisor. D was from that same mesial corner of the left central incisor to the distal corner of the right lateral incisor. The addition of measurements $A+B+C+D$ thereby gives a simple representation of the arch perimeter; that before extraction being represented by the sum of $A_1+B_1+C_1+D_1$ and that on the second set of models as $A_2+B_2+C_2+D_2$. The reduction in circumferential arch length (X) is therefore assessed by the simple subtraction:—

$$X = (A_1+B_1+C_1+D_1)-(A_2+B_2+C_2+D_2)$$

This reduction in arch perimeter is equivalent to the sum of the forward drift of $\overline{6|6}$.

Similarly, the degree of incisor crowding can be assessed by subtracting the measurements $C+D$ from the total width of the 4 incisors:—

Original incisor crowding (Y_1) = (Sum of width of $\overline{21|12}$)$-(C_1+D_1)$.

Final incisor crowding (Y_2) = (Sum of widths of $\overline{21|12}$)$-(C_2+D_2)$.

Therefore, relief of incisor crowding (Y) = Y_1-Y_2.

This figure (Y) may clearly be either a positive or negative figure depending on whether there has been a relief of incisor crowding (if present) or a deterioration.

In order, therefore, to arrive at the total space closure which has occurred, both by forward drift of molars (X), and by relief of incisor crowding (Y) these two figures simply have to be added:—

Total space closure = $(X+Y)$.

RESULTS

After excluding those cases where subsequent extractions had invalidated certain measurements, 118 cases were used of which 52 were male and 66 were female. Patients were divided into those recorded as having competent lips (76 cases) and those having incompetent lips (42 cases). They were also divided into groups based upon skeletal and occlusal patterns determined clinically. On examination it was found that the number of occlusal Class II, division 2, cases was too small to form a statistically significant group and so a simple division was made into occlusal Classes I, II, and III (*Table II*). The unusually high proportion of cases with a Class III skeletal pattern may show an individual tendency on the part of the clinician to err slightly on the side of mandibular prognathism, as the proportion of these cases is higher than that commonly found in such surveys.

Table II.—The Distribution of Skeletal and Occlusal Patterns (Determined by Clinical Assessment)

Pattern	*Class I*	*Class II*	*Class III*
Skeletal	62	18	38
Occlusal	67	39	12

Space Closure in Total Sample

The amount of space closure that occurred was first investigated in the total sample and it was at once evident that clinical experience is supported by the figures. In all but 3 cases the buccal segments moved forwards and in 98 cases (83 per cent), the lower premolar spaces closed completely. It is interesting to note that on average over 90 per cent of space closure occurs by the forward movement of the buccal segments. Less than 10 per cent occurs by the dropping back of the canines and the relief of incisor crowding

(*Table III*). Furthermore, the degree of lower incisor crowding does not appear to be statistically related to the degree of space closure, i.e., space closure is no greater in those cases where

Table III.—Space Closure in the Total Sample

Space Closure	*Mean*±S.D. (in mm.)
By forward movement of lower molars (X)	9·0±4·4
By relief of incisor crowding (Y)	0·7±0·8
Total ($X+Y$)	9·7±4·8

the incisors were originally crowded than in those where the incisors were originally spaced.

Space Closure in Relation to Sex and Competent or Incompetent Lips

No relationship could be found between space closure and sex distribution, but there proved to be a strong correlation between space closure and competent lips, a finding for which no adequate explanation can be offered (*Table IV*).

Class II cases, owing both to forward drift of buccal segments (X) and to relief of incisor crowding (Y), was considerably less than in Class I or Class III cases (*Table V*). This correlation between smaller amounts of space closure in skeletal Class II cases may be explained by a tendency for these cases to be more crowded originally, the hypothesis being that the lower buccal teeth were already in a forward position and little further mesial drift occurred. It might even be postulated that buccal segments have a ' forward-drift potential ', and that this has been more nearly fulfilled in Class II, crowded, lower arches than in the other two skeletal or occlusal groups.

In order to try to corroborate this a further examination was carried out, which showed that there is a much greater degree of crowding in the mandibular arches of Class II cases (as one would expect). Assuming a constancy of tooth size throughout the sample a comparison of arch lengths ($A+B+C+D$), as shown in *Table VI*, gives an indication of degrees of crowding.

Table IV.—Space Closure in Relation to Sex and Competent or Incompetent Lips

	N	X (Mean±S.D. in mm.)	t	Y (Mean±S.D. in mm.)	t	$X+Y$ (Mean±S.D. in mm.)	t
Male	52	9·35±4·55	0	0·10±1·14	1·18	9·39±4·89	0·23
Female	66	9·35±4·64		0·32±0·9		9·60±4·98	
Competent lips	76	10·34±4·46	3·37*	0·34±0·96	1·7	10·68±4·58	3·72*
Incompetent lips	42	7·50±4·25		0·01±1·10		7·34±4·84	

* Significant at a 1 per cent level.

Table V.—Space Closure in Relation to Skeletal and Occlusal Patterns

Pattern	*N*	X (Mean±S.D. in mm.)	t	Y (Mean±S.D. in mm.)	t	$X+Y$ (Mean±S.D. in mm.)	t
Skeletal I	62	9·80±4·52	3·28*	0·16±1·14	0·33	9·89±4·94	2·89*
Skeletal II	17	5·82±4·35		0·26±1		6·09±4·55	
Occlusal I	66	10·5 ±4·2	4·76*	0·70±0·7	0·67	10·9 ±4·4	5·26*
Occlusal II	39	6·6 ±3·9		0·80±0·8		6·3 ±4·3	
Skeletal II	17	5·82±4·35	3·63*	0·26±1	0·16	6·09±4·55	3·35*
Skeletal III	38	10·18±4·14		0·30±0·81		10·42±0·73	
Occlusal II	39	6·60±3·9	1·99	0·80±0·8	0·12	6·30±4·30	2·22†
Occlusal III	12	9·10±3·4		0·70±0·8		9·30±3·50	

* Significant at a 1 per cent level.
† Significant at a 5 per cent level.

Relation to Occlusal and Skeletal Patterns

The relationship between space closure and occlusal and skeletal patterns varied from the expected result. It was found that closure in

Rate of Space Closure

The amount of space closure due to forward movement of buccal teeth seems to continue until between 4 and 6 years following extraction.

However, a comparison of space closure occurring between 4–6 years and over 6 years shows no statistically significant difference, and it would appear that, in general, space closure is virtually complete after 6 years or so (*Table VII*).

It is interesting to note that there is no significant relationship between the relief of incisor crowding and the passage of time, as might be expected from the earlier finding of the very much greater movement of the buccal segments than of the incisors which occurs.

Table VI.—Arch Lengths in Relation to Occlusion

Occlusal Class	N	Arch Length (Mean ± S.D. in mm.)	
I	67	75·9 ± 2	4·02*
II	39	72·8 ± 1·7	

* Significant at a 1 per cent level.

absence of lower third molars does not influence space closure up to 12 years of age.

Other Factors

No statistical relationship was found between the rate or extent of space closure and the degree of cuspal interdigitation—roughly assessed. Nor was there any evidence of upper arch treatment having an effect on space closure. This applied both to treatment involving distal movement of the buccal segments as well as to retraction of the upper labial segments, with any possibly concomitant tendency to forward movement of the upper buccal segments that might have existed.

DISCUSSION

The prime object of this investigation was to establish quantitatively whether spaces do close following the loss of the lower first premolars, and this they undoubtedly do. Space closure was complete in 83 per cent of cases. It would therefore seem that the application of time and effort

Table VII.—Space Closure Related to Time from Extraction of $\overline{4|4}$ to Date of Second Impression

Time	N	X (Mean ± S.D. in mm.)	t	Y (Mean ± S.D. in mm.)	t	$X+Y$ (Mean ± S.D. in mm.)	t
Less than 4 years	32	6·8 ± 4	3·14*	0·9 ± 0·8	1·29	6·9 ± 4·6	2·96*
4–6 years	59	9·6 ± 4·1		0·7 ± 0·7		9·8 ± 4·4	

* Significant at a 1 per cent level.

Table VIII.—The Relationship of Presence or Absence of $\overline{8|8}$ to Space Closure owing to Forward Movement of Lower Molars

Presence or Absence of $\overline{8|8}$	Patients under 12 yr. at Time of X-ray					Patients 12 yr. and over at Time of X-ray				
	N	X (Mean ± S.D. in mm.)	t	$X+Y$ (Mean ± S.D. in mm.)	t	N	X (Mean ± S.D. in mm.)	t	$X+Y$ (Mean ± S.D. in mm.)	t
$\overline{8|8}$ present	64	10 ± 4·6	0·94	10·1 ± 4·9	0·78	17	6·4 ± 3·2	0·57	6·5 ± 3·9	0·31
$\overline{8|8}$ absent	32	9·1 ± 3·9		9·3 ± 4·5		5	5·5 ± 2·3		5·9 ± 3	

Presence or Absence of Third Molars

It was surprising to find that in the total sample there was no statistical evidence that the presence or absence of third molars influenced space closure (*Table VIII*). This conclusion was reached by comparing groups above and below 12 years of age, and it is felt that if X-rays had been available of an older initial age-group (when third molars were more certain to be present on the X-rays) a different result might well have been obtained. In the meantime, however, it would appear that the presence or

to closing lower residual spacing with complex appliances is probably unnecessary in all but a very small percentage of cases.

The closure of these spaces is very largely due to forward movement of buccal teeth. It would appear that very little space is needed for the relief of incisor crowding (less than 1 mm. on average). It is virtually impossible to establish a quantitative degree of incisor crowding which is universally applicable, or to describe exactly what constitutes an acceptable rather than an ideal incisor alinement. However, it was estimated

that an acceptable alinement of the incisors was achieved in 94 out of the 118 cases.

Space closure is directly related to the degree of total arch crowding present but not to the degree of incisor crowding. This possibly explains the fact that space closure in Class II case was less than either in Class I or Class III cases, it being postulated that forward movement of $\overline{6|6}$ had already occurred in these cases. However, an alternative possible explanation has been suggested by Mills (1970) to the effect that cuspal interference during treatment may influence the lack of forward movement of the buccal segments in such cases. When upper arch treatment is being carried out the upper first molars are held in place by the appliance and they, by cuspal interference, might hold the lower molars back. Lower spaces would tend to remain while upper treatment proceeds. In favour of this argument is the fact that all but 7 of the Class II cases did receive upper arch treatment, and of those 7 occlusal Class II cases who did not have upper arch treatment, only 3 were diagnosed as also having a Class II skeletal base relationship.

The presence or absence of third molars on X-rays in patients under 12 years of age does not appear to influence the degree or rate of space closure. This, however, does not necessarily apply to older age-groups, where clinical experience suggests that the reverse applies.

Finally, it is worth commenting that there is a well-proven connexion between the loss of first premolars and a decreased incidence of third molar impaction. As already mentioned in the review of the literature, Björk and others (1956), Faubian (1968), and others have all shown such a correlation to be highly significant. The degree of forward movement of the buccal segments subsequent on the loss of the lower first premolars found in this investigation would seem to offer further corroboration to the likelihood of this being true.

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A COMPREHENSIVE TREATMENT OF THE SEVERE CLASS II, DIVISION 1, MALOCCLUSION

L. A. USISKIN, B.D.S., F.D.S., D.Orth.

Senior Lecturer in Orthodontics, Guy's Hospital Dental School

W. G. WEBB, B.D.S., F.D.S., D.Orth.

Senior Registrar, Orthodontic Department, Eastman Dental Hospital

INTRODUCTION

THE object of this paper is to present a comprehensive treatment procedure for the Class II, division 1 malocclusion, on moderate and severe Class II skeletal patterns, utilizing both removable and fixed appliances. This is not a new technique but a procedure that has been built up over the years at the Eastman Dental Hospital, London, and one that we feel is particularly applicable to orthodontic practice in this country.

Essentially, following the loss of sufficient teeth the upper canines are retracted and the overbite is reduced with a removable appliance, after which fixed appliances are inserted and the overjet is reduced utilizing apical control. The gradual and logical build-up of the appliances as treatment progresses will be shown, which is unlike the more time-consuming initial full-banding procedures required in some multiband techniques. The fixed-appliance technique used here is based on that described by Hill (1954) and subsequently by Briggs (1960, 1966) and Parker (1965), which utilized the Ripple bracket and round wire working arches. Many changes have been made since then—Siamese Edgewise brackets have replaced the Ripple bracket because of the greater accuracy of bracket engagement, and much lighter gauge wires are now used initially to produce tooth alinement.

In this paper diagnosis will not be given in detail, it being presumed that the four first premolars are the teeth of choice for extraction.

The initial aim is to retract the upper canines into a Class I relationship with the alined lower canines. Although removable appliances generally promote tilting of the teeth, such appliances, if necessary augmented by extra-oral anchorage, are useful for producing the initial retraction of the upper canines. Considerable anchorage is provided by the palatal coverage and overbite reduction can begin immediately with the use of an anterior bite-plane. Adequate overbite reduction is essential if the upper incisors are to be retracted fully into a stable position. Whilst the upper canines are being retracted there is often considerable spontaneous lower incisor alinement. A lower fixed appliance is then used to aline the teeth fully, correcting any rotations and further reducing the overbite. Following this there is usually some residual lower arch space which is utilized to provide Class II traction to the upper incisors during overjet reduction, so bringing forward the lower molars into a Class I relationship.

Where the upper incisors are upright, reduction of the overjet will require apical control if severe retroclination and a Class II, division 2, type of incisor relationship is to be avoided. Indeed, in some cases the stability of the final result is dependent upon achieving bodily movement of the upper incisors (Ballard, 1967), and this movement can only be satisfactorily carried out with a fixed appliance. The effect of such an appliance on the upper incisors compared with that obtained with a removable appliance can be seen in *Fig.* 1. At *Fig.* 1a the incisors have been retracted with a removable appliance and the teeth have rotated around a fulcrum formed between the middle and apical third of the root. The apices have thus moved forward, and in some cases this is indeed desirable. The two tracings on the right show the results of attempting to move the apices palatally with a fixed appliance. This would be brought about by a torque-force in the archwire transmitted to the tooth by means of Begg spurs. In *Fig.* 1b the degree of torque is just enough to

Paper presented at the Scottish Meeting held in Aberdeen on 23 October, 1970. Original table demonstration presented at the Country Meeting of the B.S.S.O. held in Brighton in May, 1970.

rotate the tooth around its apex, thus preventing the apex from moving forward. In *Fig.* 1c the torque has been increased so that the incisors have actually moved bodily. Where bodily movement is attempted the use of extra-oral anchorage is essential in nearly all cases, since that provided by the posterior teeth of either arch would be inadequate.

Any Class II, division 1 malocclusion may be treated with this procedure though it is particularly suitable for those cases where there is a

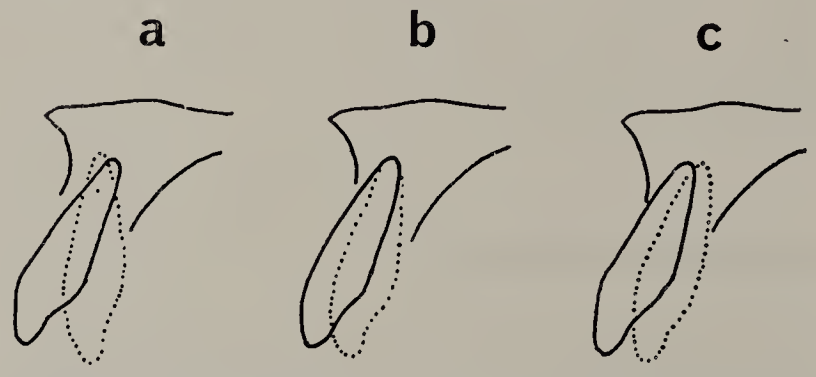


Fig. 1.—Retraction of upper incisors using (a) a removable appliance, (b) a fixed appliance limiting labial movement of the apex, and (c) a fixed appliance producing bodily tooth movement.



Fig. 3.—Removable appliance used to retract the maxillary canines (viewed from the undersurface). The canine springs and separate 0·5-mm. guard wires are visible.

severe skeletal discrepancy. A typical case on moderate Class II dental bases is shown in *Fig.* 2. The lips are incompetent, the lower lip acting behind the upper incisors. The overjet is increased with fairly upright upper incisors and there is an increased and complete overbite. Typically the lower incisors are crowded and the molar relationship is Class II.

For the purposes of this paper the technique to be described is divided into four stages. It must be emphasized, however, that these are not necessarily separate and in practice the various stages overlap.

STAGE A

Full orthodontic records should be obtained and a complete diagnosis and treatment plan outlined. A fresh working impression of the intact upper arch is then taken and the four first premolars extracted about 1 week before fitting the initial removable appliance.

Removable Appliance Design

The appliance (*Fig.* 3) is retained by means of 0·7-mm. Adams' clasps on the first molars

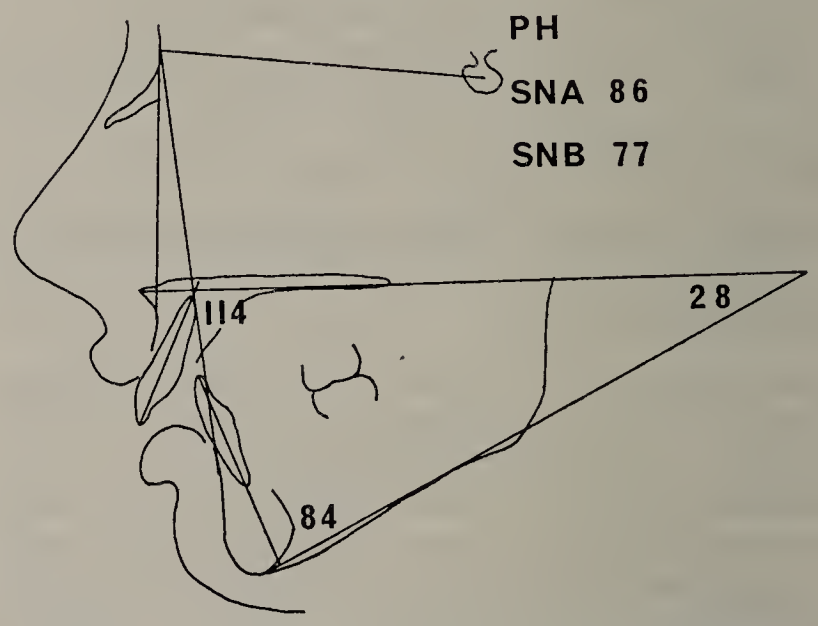


Fig. 2.—Tracing of a lateral skull radiograph showing a typical severe Class II, division 1 malocclusion on a Class II skeletal pattern.

(Adams, 1957), and a 0·7-mm. labial bow closely fitted to the upper central incisors with small adjustment loops close to the distal margins. Palatal springs, 0·5 mm. in diameter, approximately 18 mm. long, are used to retract the upper canines. Separate 0·5-mm. guard wires are placed in the base-plate between the springs and the palatal mucosa to prevent any tendency for these springs to impinge on the mucosa during use. In order to minimize distal tilting, the working arms of the springs are placed mesial to the canines as close to the gingival margins as possible and activated by approximately 2 mm. each month. This produces 1·2-mm. retraction of the canines between each visit.

The acrylic covering the palate is built up into a flat anterior bite-plane, extending from the distal of each canine. On fitting the appliance the acrylic is so adjusted that when the lower incisors contact the bite-plane the posterior teeth are separated by not more than 2 mm. These minimal bite-planes seem well tolerated from the start, and at succeeding appointments cold-cure acrylic is added to increase the height of the bite-plane so as to even out the often crescent-like form of the incisor tips and eventually to ' depress ' the lower incisors and canines. The aim at the end of this phase of treatment is to level out the lower incisors so that they are even in height with the

overbite reduced almost to an ' anterior open bite ' position.

The fitted labial bow serves to increase the anchorage and retention, since the teeth are prevented from tilting by the bow labially and the acrylic palatally. The anchorage can be further reinforced by engaging the metal arms of an extra-oral headgear on to mesial pointing, soft, 0·7-mm., wire hooks, which are tack-welded and then soldered to the loops of the labial bow (*Fig.* 4). The extra-oral anchorage headgear



Fig. 4.—Upper removable appliance, anterior view. Note the fitted labial bow on $\underline{1|1}$ with soldered 0·7-mm. soft wire hooks for attachment of the extra-oral anchorage.

preferred is the ' Northwest ' full headcap type and is adjusted so that when the arms are attached to the removable appliance there is an upwards and backwards pull. For extra-oral anchorage the force applied need only be moderate (300 g. each side), with the headgear being worn each night whilst in bed for approximately 10 hours (*Fig.* 5).

Clinical Technique

Retraction of the maxillary canines takes between 4 and 8 months, the aim being to place them just better than Class I to the eventually alined position of the lower canines. Although every effort is made by the use of gentle forces to minimize the tilting of the maxillary canines, since these teeth often have to be moved long distances some tilting becomes inevitable. In many cases we have noted in the succeeding stages of the technique, where the canines are merely prevented from moving forwards, that a high degree of spontaneous uprighting occurs, the tilting apparently being largely self-correcting. During the use of the removable appliance the lower arch is closely observed to ensure that no rapid loss of space occurs by mesial drift. It is certainly noted that a reasonable degree of self-alinement takes place and this allows for the easier preparation and insertion of the bands in the lower arch. Additionally, with a slight amount of mesial drift the molar relationship is seen to improve as the lower first molars move more towards Class I.

At each routine appointment several of the bands for the lower arch are prepared, and before the maxillary canines have been fully retracted all the lower bands should have been cemented into position and the working archwires fitted.

Preformed bands are chosen for the lower canines, second premolars, and first molars. The lower incisor bands are drawn up by hand using 3·5×0·08-mm. tape, onto which have been



Fig. 5.—Extra-oral anchorage in position.

welded 0·55×0·71-mm. small Siamese Edgewise brackets. The lower incisor bands are formed so that the brackets lie halfway up the clinical crowns of the teeth and at right angles to their long axes. Medium width Siamese brackets are now welded to the preformed bands chosen for the lower canines and second premolars and rectangular buccal tubes are welded to the buccal aspect of the lower first molars, parallel to the occlusal surface (*Fig.* 6). In those cases where one of the main problems will be the provision of an adequate reduction of the overbite the lower second permanent molars are banded, and these teeth carry the buccal tubes, whilst a wide Siamese bracket is placed on the lower first molars.

It is important to ensure that the distances between the tips of the cusps and the central channel of the brackets are the same for all teeth,

as are the distances between the tips of the lower molar cusps and the centre of the tube (*Fig.* 6). This is to enable archwires to aline and depress all the teeth evenly without any need for repeated compensatory bands in the vertical plane. The exceptions are the lower canines where the brackets may be set slightly more incisally to ensure that these teeth are adequately taken beneath the general level of the occlusal plane, so preventing them from interfering with the required movements of the maxillary dentition.



Fig. 6.—Lower arch bands in place with brackets and buccal tube at the correct height.



Fig. 7.—A Kloehn type of face bow in position attached to bands on $\underline{6|6}$.

bands to the neck strap, the tension is so adjusted to give a force of approximately 450 g. on each side. The appliance (*Fig.* 7) should be worn for not less than 12 hours a night and the upper first permanent molars moved back far enough to produce the required space. Once the extra-oral traction is being worn well the four first premolars are extracted. This will allow the canines to drop back somewhat before being actively retracted. If there is posterior crowding in the maxilla and distal movement of the upper first permanent molars is slow, then, provided that the third molars are present, the upper second permanent molars may be extracted. Tension on the head-gear is now reduced to about 300 g. on either side and an upper removable appliance, similar to the one previously described, is inserted to retract the upper canines. Posterior retention (*Fig.* 8) in this case, however, is provided by recurved clasps in 0·7-mm. wire around the buccal tubes on the upper first permanent molars (Plint, 1961). The appliance also carries a flat



Fig. 8.—Retention for the removable appliance provided by a 0·7-mm. recurved clasp around the buccal tube on the upper first permanent molar band.

Additional Feature

A variation in this stage is required in some cases. Where the molar relationship is a full unit Class II or more, and this is associated with lower incisor crowding, then more than one unit of space will be required in the upper arch if the upper canines are to be placed in a Class I relationship with the lower canines. This space may be provided by further extractions or more usually by the distal movement of the upper first permanent molars prior to the retraction of the upper canines (removing the second permanent molars if this is thought to be necessary).

Before any extractions are carried out the upper first permanent molars are banded and double tubes are soldered to the buccal aspect, a 1·15-mm. tube occlusally and a 0·9-mm. tube gingivally. A Kloehn type of face bow is constructed with an inner arch of 1·15-mm. wire and an outer bow of 1·5-mm. wire. By using differing sizes of elastic anterior bite plane as before to commence overbite reduction.

STAGE B

By this time all the lower bands have been cemented on to the teeth. During this phase of treatment lower archwires are inserted to produce bracket alinement and to maintain overbite reduction. The upper bands are constructed with the correct attachments, and archwires are inserted to aline the teeth prior to overjet reduction.

Archwires are formed mainly from austenitic stainless-steel wire, heat-treated and cold-drawn to give sufficient strength and flexibility. Flexible archwires are needed initially to produce bracket alinement. Usually these are 0·35-mm. or 0·40-mm. diameter wire or a multistranded archwire. If necessary the flexibility of a wire may be increased by the incorporation of loops or third

power bends. These have been described by Hill (1954) and Begg (1956) and simply increase the length of wire incorporated in the archwire (*Figs.* 9, 10). Twistflex (Unitek) and Orthoflex (Dentaurum) examples of multistranded wires are fine cables of three wires twisted tightly together to produce varying sizes (Eirew, 1969).

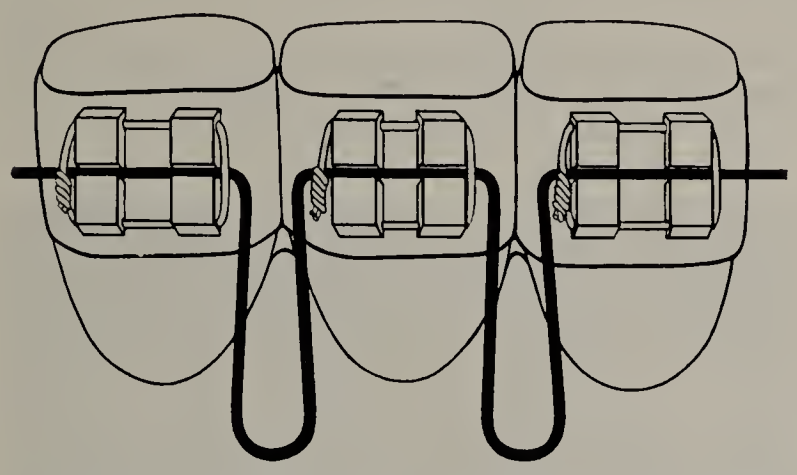


Fig. 9.—Vertical loops or third power bends which locally increase the flexibility of an archwire.

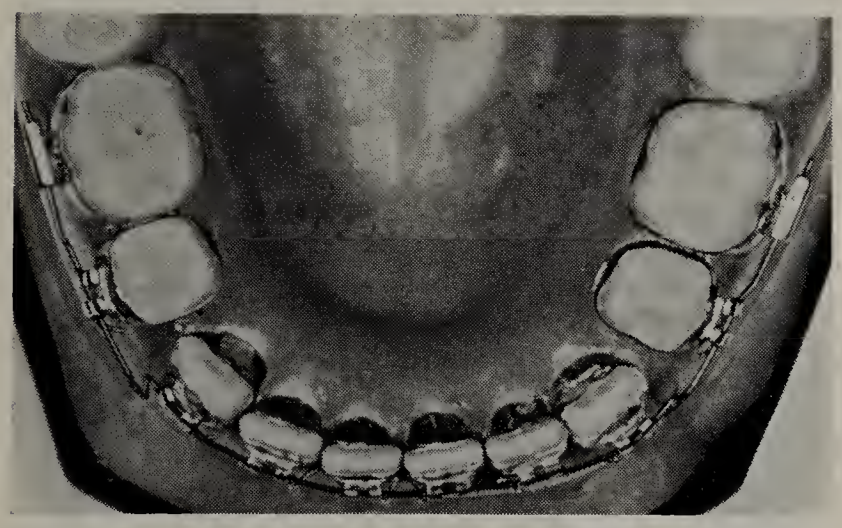


Fig. 11.—Occlusal view of a 0·45-mm. space-closing archwire in position. Note the space-closing loops in the first premolar regions, and the ' ideal ' arch form with horizontal offset bends between the canines and second premolars, and the second premolars and molars. A straight wire between these brackets would otherwise not allow for the normal buccolingual differences in tooth width.

They are extremely flexible and are ideal for initial bracket alinement, 0·45-mm. diameter wire usually providing sufficient flexibility.

Once the brackets have been alined heavier archwires are inserted—0·40-mm. followed by 0·45-mm. wire. These arches may contain third power bends if there are any rotations to be corrected. The final 0·45-mm. arch should possess bayonet bends to maintain individual tooth-overcorrections if necessary, and space-closing loops in the premolar region. The space-closing loops, when activated, produce an intra-maxillary force which will be described later. All archwires are formed to the ideal arch form, as described by Tweed (1966), with molar and premolar offsets and a slight ' toe-in ' in the molar region if required (*Fig.* 11). This reduces the tendency for the lower molars to rotate mesiolingually as they are brought forward. The lower archwires also possess a reverse curve of Spee to maintain and further aid overbite reduction. When viewed from one side the wire is crescent-shaped so that when

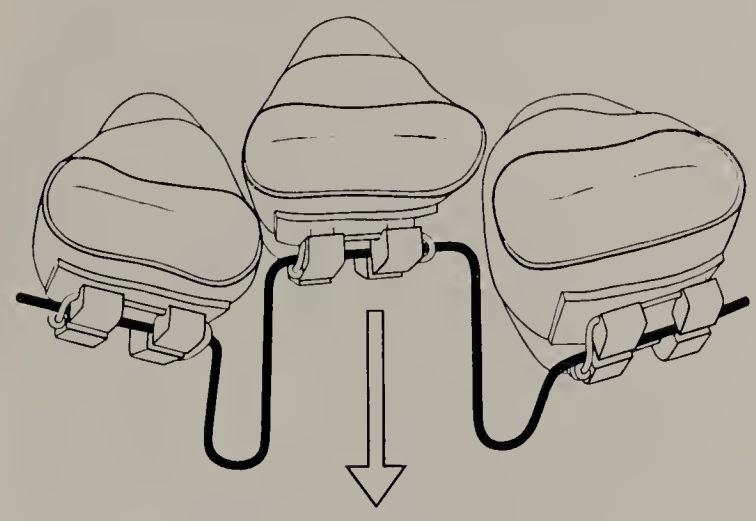


Fig. 10.—Third power bends viewed from above. The ' gate ' between the two vertical loops has to be moved from its ideal position and tied into the bracket of the displaced incisor. The resultant force tends to pull this tooth into the line of the arch.



Fig. 12.—Lower archwire showing the reverse curve of Spee in its passive position when inserted into the buccal tubes only.

inserted into the buccal tubes the arch would tend to lie in the lower labial sulcus (*Fig.* 12). The reverse curve is accentuated by the tip-back bend placed distal to the lower second premolar brackets; this aids anchorage by preventing rapid forward movement of the lower first molars during the forthcoming stage.

The archwires are ligatured tightly into position with 0·25-mm. soft, stainless-steel wire or with Alastik Rings. These are small rings made from an elastic plastic material and inserted by grasping them with a fine pair of artery forceps and hooking them over the wings of the bracket. The aim of this phase is to have the lower 0·45-mm. archwire in situ before the upper removable appliance is left off, otherwise the overbite may re-establish itself. The upper first permanent molars are now banded and an impression is taken with the bands in position. The bands are then transferred to the impression which is cast in stone.

On this model is constructed a 1-mm. palatal arch which is soldered to the bands. The palatal arch extends as far forward as the canines and crosses the palate, leaving plenty of space palatal to the incisors to allow for their unimpeded



Fig. 13.—Palatal arch attached to $\underline{6|6}$ bands with soldered 0·7-mm. soft mesial stops to hold $\underline{3|3}$; $\underline{21|12}$ have been banded and a free-sliding twin wire arch inserted to commence alinement of the incisors.

retraction (*Fig.* 13). Spurs, 0·7-mm., are soldered to the palatal arch to maintain the upper canine position, and double tubes are soldered on the buccal aspect of the first permanent molar bands —a 1·15-mm. tube occlusally and a 0·9-mm. tube gingivally.

The upper canines and premolars remain unbanded in this technique, allowing for spontaneous canine uprighting. In addition, any procedure which involves the banding of the canines and premolars requires that overjet reduction can only take place utilizing an archwire tied into the brackets and with space-closing loops. If, when these are activated, extra-oral anchorage is not worn for some reason the effect on the upper arch will be to bring forward the upper buccal segments, thus losing anchorage. With the method to be described, utilizing the palatal arch, overjet reduction takes place with a free sliding archwire and elastic traction. Thus, as a fail-safe mechanism, where one is relying on extra-oral anchorage, it should be stressed that if for any reason the headgear cannot be worn then, in addition, the elastics must be left off.

Once the lower arch treatment is well under way the palatal arch is cemented in place (*Fig.* 14). Extra-oral anchorage is continued at night either by attaching the full headgear to a stopped 1·15-mm. labial arch inserted into the first molar occlusal buccal tubes, or with a cervical face bow, as described previously. If the palatal arch and headgear are inserted one visit before the upper incisors are banded, incisor alinement and some spontaneous reduction in overjet will often occur.

The upper incisors are now banded, usually carrying wide Siamese brackets on the upper central incisors and medium-size brackets on the upper lateral incisors (depending on individual tooth width). The brackets are now alined and any rotations are corrected with some form of



Fig. 14.—Side view of the upper palatal arch soldered to $\underline{6|6}$ bands with stops mesial to $\underline{3|3}$. Note the buccal tubes, 1·15 mm. occlusally and 0·9 mm. gingivally, and the lower 0·45-mm. archwire with space-closing loops. The upper incisors are unbanded and free to aline.



Fig. 15.—Anterior view of the twin wire arch inserted to aline the upper incisors. The arch is tied in with an Alastik chain which also closes anterior spacing.

alining archwire. Ideal for this is the twin wire arch as described by Johnson (1934) and Mills (1959) (*Figs.* 13, 15). Alternatively, a multi-stranded archwire in end tubes similar to a twin wire arch may be used to the same effect. The archwire is ligated into the brackets as before, either with stainless-steel ligatures or with Alastiks. It is important at this point to close all anterior spacing as this enables the final torquing archwire to be easily inserted at the next stage. Anterior space closure may be carried out with compressed coils produced by 0·15-mm. wire wound on to a 0·7-mm. core, though alternatively a much easier method is afforded by the use

of Alastik chains. A link of four modules is needed. The first module is slipped over the wings of an upper lateral incisor bracket. The link is then stretched and the adjacent teeth are

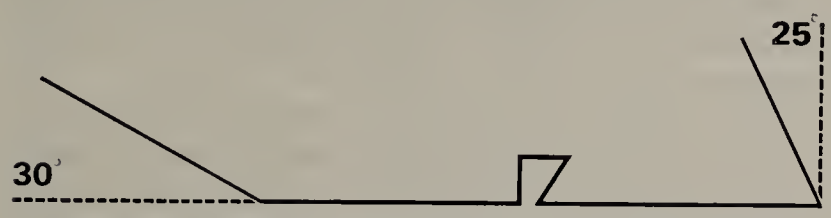


Fig. 16.—Diagram of the upper Begg spurred archwire viewed from the side.

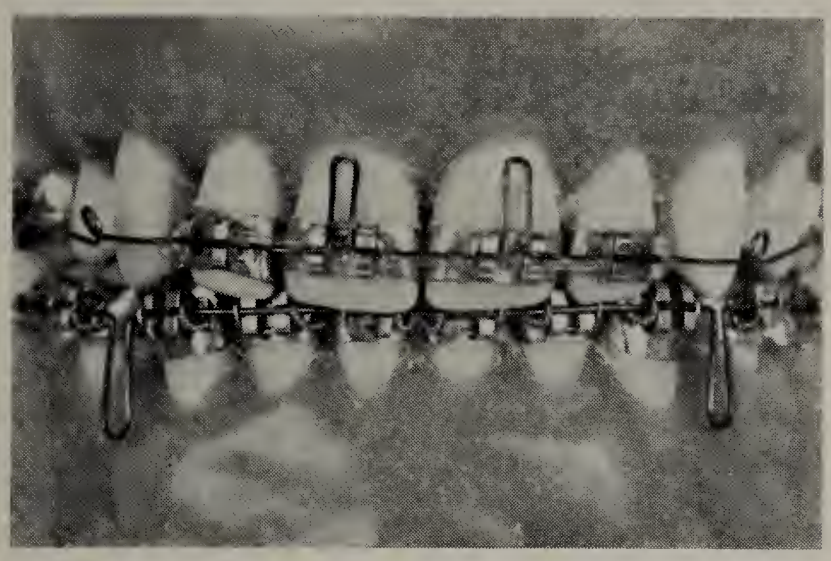


Fig. 17.—Upper ' torquing ' archwire in position with Begg spurs lying between the two parts of the Siamese brackets.

attached in a similar way until all the four incisors are joined together. This will obviously cause a pressure to be applied to the teeth and the effect is to aline the incisors and to bring them together.

STAGE C

By now the upper and lower incisors are alined with over-correction and over-rotation if required. Some overjet reduction may have occurred already but during this stage the overjet will be reduced fully.

A 0·45-mm. gauge archwire is now inserted into the upper brackets with Begg torquing spurs on the incisors, traction hooks distal to the upper lateral incisor brackets, and 30° tip-back bends in the premolar region (*Fig.* 16). This has been described previously by Begg (1965) and Parker (1963), but since then it has been somewhat modified. The Begg spurs are bent at approximately 25° to the vertical and lie between the two parts of the Siamese brackets, ending just short of the gingival margin (*Fig.* 17). The greater the angle of the spur so the degree of torque produced is increased. Correspondingly, the force required to move the incisors is raised, producing a greater strain on the anchorage. These spurs provide the mechanism for reducing the tilting of the maxillary incisors that would normally occur whilst an overjet is being reduced with a plain archwire. Palatal movement of the apices of the incisors may sometimes be achieved if the spurs are strongly activated. Mills (1970), from tracings of a number of such completed cases, states that usually the crowns have been taken palatally while the apices have not been permitted to move labially, that is, the teeth have been moved around their apices. Spurs are usually only necessary on the upper central incisors but may be added to the upper lateral incisors if apical control is thought to be necessary for these teeth also.



Fig. 18.—Class II traction carried out with an elastic band from the anterior maxillary traction hook to the rear-facing projection of the mandibular buccal tube.

Either traction hooks or coils are bent vertically into the archwire, the coils having the opening of the helix facing outwards so as to allow for the insertion of the elastic traction. Tip-back bends are introduced in the premolar region at an angle of approximately 30° to the horizontal (*Fig.* 16). The effect of this is mainly to increase the activity of the Begg spurs and partly to produce an intrusive force on the upper incisors. This may be particularly of value where there is a deep overbite problem. It is important to remember that if for any reason a palatal arch is not being used the effect of the torquing arch when tied into the incisor brackets will be to flare out the molar teeth buccally. Under these circumstances the arch must previously be contracted across the molar region to counteract this.

The archwire is ligated only to the upper incisors, with these teeth further tied together to prevent the upper lateral incisors drifting distally. A four sectional Alastik chain would perform both these functions. The overjet is reduced by applying Class II traction of approximately 75 g. tension with latex elastic bands, measuring the force with a small tension gauge. The elastic bands are slipped over the rear-facing projections of the buccal tubes on the lower first permanent molars, and then through the upper arch traction hooks (*Fig.* 18). This force alone would tend to

move the lower arch forward, bringing the lower molars mesially and proclining the lower incisors. To prevent this proclination the lower arch is activated before being finally tied in, intramaxillary traction being introduced by pulling the ends of the archwire distally, opening the space-closing loops, and turning the archwire downwards sharply at the end of the lower first molar buccal tubes (*Fig.* 19). The aim is thus to

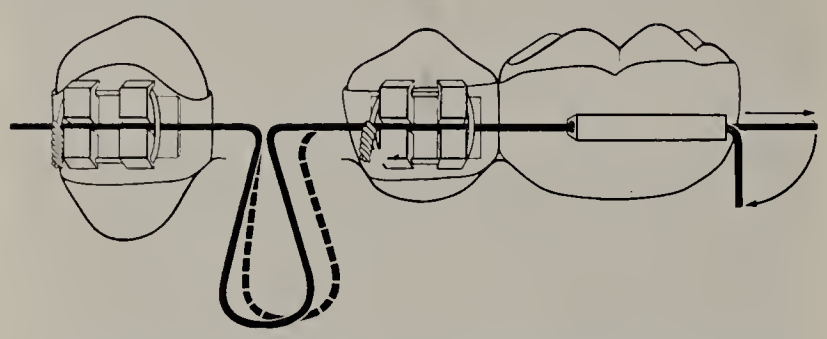


Fig. 19.—A space-closing loop opened and thus activated by pulling the end of the archwire distally and turning it down sharply behind the buccal tube.

maintain the labiolingual position of the lower incisors and to bring the lower molars and second premolars mesially *en bloc* towards a Class I relation with the position of the upper molars and second premolars. In performing these actions the lower archwire provides the anchorage for the Class II traction, whilst restricting the degree of tilting that occurs with the mesial movement of the lower posterior teeth, and counteracts the tendency for the lower incisors to be proclined.

Extra-oral anchorage is continued and where the lower arch space is limited, the Class II traction is replaced at night by maxillary arch intramaxillary traction elastics, producing approximately 100 g. pressure once the headgear is in place. Sometimes during treatment insufficient lower space becomes available for anchorage and thus Class II traction ceases to be used to reduce the overjet. In these cases the further overjet reduction will depend on upper arch intramaxillary traction and extra-oral anchorage alone. Class II retaining elastics, producing approximately 50 g. pressure, may be used during the day to aid maintenance of the reduced overbite and to hold the overjet reduction achieved.

Reduction of the overjet takes place at the rate of approximately 1–2 mm. per month, depending on the degree of root torque introduced and providing the elastics are worn fulltime as instructed. The most common cause for failure of overjet reduction is lack of patient co-operation on the wearing of elastics. If the palatal arch starts to become embedded in the palate anteriorly it is usually a sign that the headgear is not being worn. The overjet should be fully reduced in 7–9 months depending on the severity of the case.

STAGE D

By this time the overjet will have been fully reduced and the molar relationship should be almost Class I. Time may be spent at this stage in continuing to improve the maxillary incisor root positions by further activating the spurred archwire.

The palatal arch is now cut out with wire cutters, so withdrawing the mesial canine stops and leaving the first molar bands in place. In the majority of cases with some mesial relapse the canines seem in the long term to achieve a relatively upright position without further attention. However, if the maxillary canines are grossly rotated or still excessively tilted distally, then bands may be placed on these teeth and loops incorporated in the archwire to induce rotation and alinement. Occasionally occlusal locking with some part of a mandibular canine seems to prevent spontaneous maxillary canine correction. This would be a further reason for banding the upper canines at this stage and bringing them forward into contact with the maxillary lateral incisors. Although an ideal occlusion would require the canines to be in a Class I relationship, in these skeletal Class II cases the final incisor relationship often shows some increase in overbite, and thus the eventual canine relationship needs to be more towards one-half unit Class II.

In the lower arch an 'ideal' plain 0·45-mm. archwire, or even a rectangular wire with the usual molar and premolar offsets and slight reverse curve of Spee, may be inserted at this stage for final alinement and uprighting of the premolars and canines. If there is any excessive residual premolar space, especially in the upper arch, then the extra-oral anchorage is withdrawn and a combination of intramaxillary traction and/or Class II traction is continued, with the maxillary archwire anterior spurs still in place. However, it should be noted that one is rarely left with much residual space following overjet reduction in these severe skeletal discrepancy cases, and, especially in view of the frequency of late lower incisor crowding, it never does harm to leave a slight amount of lower arch spacing. Indeed, when the lower bands are removed some lower premolar spacing may re-open owing to uprighting of the second premolars and canines. Such spacing will rapidly close during the succeeding months.

Throughout the technique so far described, the patient is seen at approximately monthly intervals for the required adjustments and archwire preparations.

Retention

Once the occlusion is satisfactory, arrangements are made to remove the bands and prepare for retention.

In the lower arch, retention is rarely required except where the lower incisors were very rotated originally. In these cases the bands are removed initially from the molars and second premolars only, and the archwire is cut and adjusted to form a short intercanine retaining wire, holding the over-compensated incisor positions for up to a further 6 months. In the upper arch the bands are removed and an upper removable retainer is fitted, ideally the same day and certainly within 3 days. This removable appliance may be a (Hawley type) retainer with an 0·7-mm., ideal, curved, labial bow controlling the incisors, or, if there were incisor rotations present initially, the labial bow is made of 0·54 × 0·71-mm. rectangular wire fitted to contact the incisors accurately on their labial surface. At this stage minor adjustments to the occlusion may be carried out. Thus, by soldering an auxiliary 0·7-mm. spring to the bridge of the first molar clasps, buccally placed canines or second molars may be moved palatally.

Retention is usually carried on for 6–12 months, depending on lip morphology and the original rotations. Full-time retention is continued for approximately 4 months, during which the appliance is worn 24 hours a day, and this is then followed by night-time wear until retention is ceased. During this time the patient's appliance need only be checked at periods of approximately 2 months.

Theoretically, if the upper incisors have been placed in a stable position in relation to the lower lip, retention should be unnecessary. In practice, however, it does take some months for the teeth to become clinically firm and the teeth should be retained at least until this is achieved. In addition, having successfully carried out the required tooth movements, we are unwilling to release a case rapidly and thus tend to continue retention for the longer period. During this stage with the bands removed and the surgery visits relatively infrequent, co-operation is usually fully maintained. When retention is ceased there is usually some slight movement of the teeth towards their original position. Thus, after the retention period a case should be carefully and meticulously observed in comparison with study models taken at the time the retainer was withdrawn.

We believe that with practice such treatment should take between 15 and 18 months of active appliance therapy, followed by approximately 9 months of retention. The lower fixed appliance is in place for about a year, and the bands on the maxillary incisors for between 9 months and a year.

CASE REPORTS

Case 1

S.C., a male aged 11½ years at the start of treatment.

This patient had a moderate Class II skeletal pattern. The lips were incompetent, with the lower lip acting behind the upper incisors. Both the upper and lower incisors were slightly proclined with an increased overjet of 10 mm. and an increased but just incomplete overbite. Very little crowding was present. The molar relationship was one-half unit Class II on the right and a full unit Class II on the left.

The four first premolars were extracted, and an upper removable appliance supported by extra-oral anchorage was worn for 8 months to retract the upper canines and to reduce the overbite. The lower arch was banded for 20 months and the upper arch for 13 months, during which time the overjet was reduced with a Begg spurred arch and a combination of Class II and intramaxillary traction. Extra-oral anchorage was discontinued after 6 months of upper arch fixed appliance therapy. The palatal arch was removed and the upper canines and premolars were banded to aline the canines finally and to close some residual spacing. The tracing at the end of treatment showed the lower incisors to have been retroclined slightly during treatment, but these came forward as expected once the bands were removed.

The final models showed the results 6 months after the end of retention. Active treatment took 22 months followed by 5½ months' retention.

Case 2 (*Fig.* 20)

J.S., a female aged 11¾ years at the start of treatment.

This patient had a fairly severe Class II skeletal pattern with a high maxillary-mandibular-plane angle. The lips were incompetent with a short upper lip. The upper incisors were slightly proclined with an overjet of 14 mm., and the overbite was increased and complete, with the lower incisors biting into the vault of the palate. The molar relationship was a full unit Class II and there was considerable lower arch crowding.

It was felt that the loss of the first premolars only in the upper arch would not provide sufficient space to reduce the overjet. Therefore, following the extraction of the four first premolars extra-oral traction to bands on the upper first permanent molars was required for a period of 4 months before a Class I molar relationship was approached. The final molar relationship is achieved in this case as much by forward movement of the lower first permanent molars as by distal movement of the upper molars.

The initial removable appliance was then inserted (using a recurved clasp around the buccal tubes on the upper first permanent molars), continuing the use of extra-oral anchorage, and followed by the build-up of the lower fixed appliance. The upper arch was banded for 11 months for alinement of the incisors and reduction of the overjet with apical control, the extra-oral anchorage being discarded after 7 months of this time. An upper removable retainer was worn fulltime for 3 months and nocturnally for 4 months.

Because of the original position of the lower incisors some proclination of the lower incisors was thought to be permissible and this has in fact remained stable (approximately 7° increase in the angle of the lower incisors to the mandibular plane). Because of the severity of the case a slightly increased overbite has resulted and, therefore, the canines and molars do not need to be Class I in this case.

The final models (*Fig.* 20 I, J, K) show the results 5 months after the end of retention. Full-time active treatment took 18 months and retention 7 months.

Case 3

V.G., a male aged 18 years at the start of treatment.

This patient had a Class II, division 1 malocclusion on a reasonably normal skeletal pattern but with incompetent lips. The upper incisors were very proclined at 126° with an overjet of 11 mm. The overbite was increased and complete with the lower incisors biting onto the palate. Crowding was present, especially in the lower arch, with the lower left canine badly displaced and short of space. The molar relationship was Class I on the right and one-half unit Class II on the left, with the left molars and second premolars in crossbite but with no mandibular displacement.

There was not such a severe skeletal discrepancy in this case as in some of the previous cases, but it demonstrated treatment in the older patient.

The first premolars were extracted and an upper removable appliance only was worn for 6 months. The lower fixed appliance was in position 2 months before the insertion of the upper, which was reinforced with extra-oral anchorage. The lower bands were withdrawn after 7 months and the upper fixed appliance after 8 months, the overjet having been fully reduced with apical control. This was followed by the use of a full-time removable retainer for 3 months and nocturnal retention for 2 months.

The final models were to the end of retention only, although there had been no further change in the incisor relationship. Active treatment took 16 months, followed by 5 months' retention.

The upper canines were somewhat over-retracted and there was residual spacing mesial to the upper left canine. This tooth had been slow to upright and come forward.

The patient was keen to cease appliance wear, though ideally the canines should have been uprighted and the space closed.

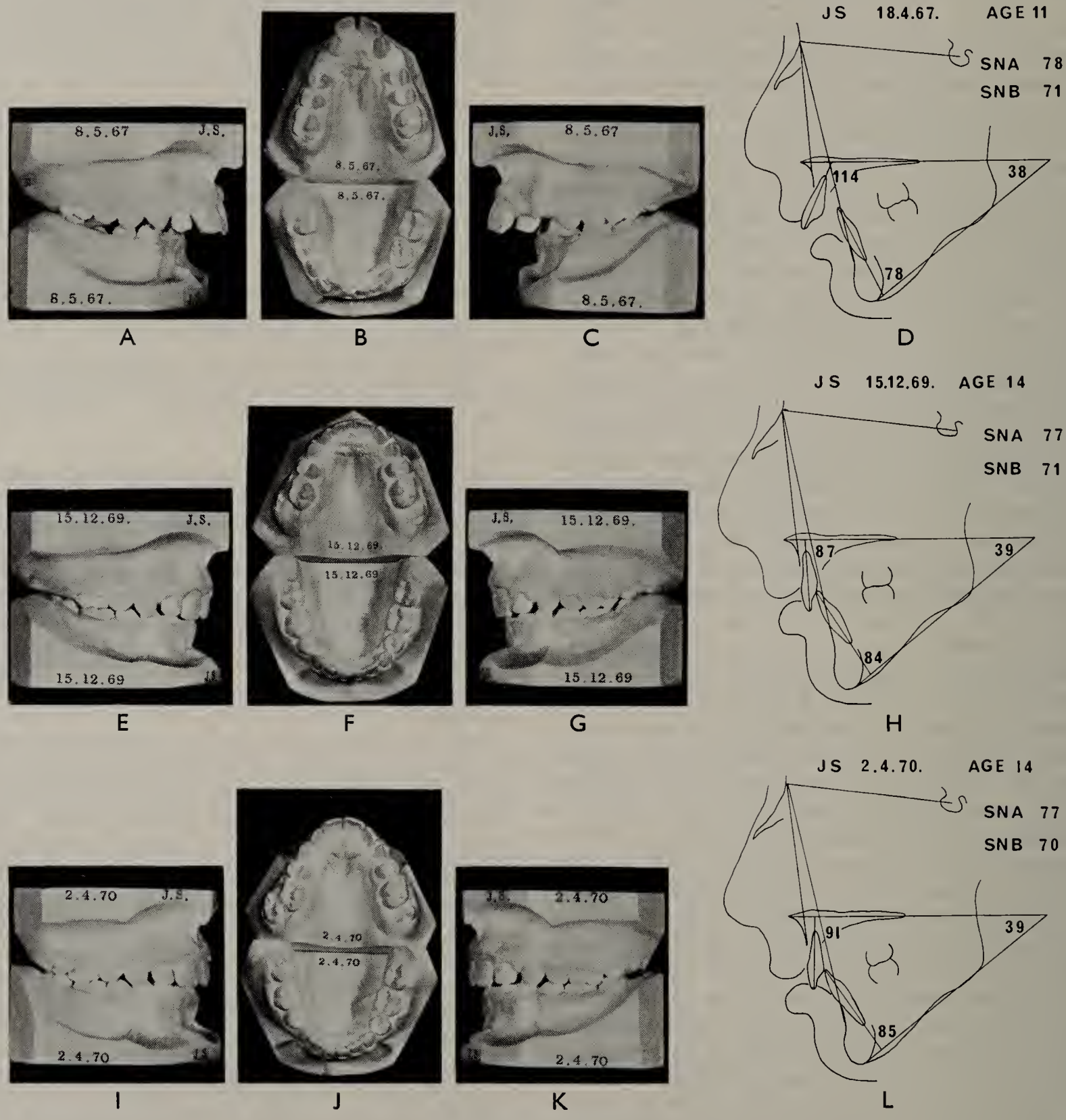


Fig. 20.—*Case* 2.

Case 4 (*Fig*. 21)

S.C., a female aged 10½ years at the start of treatment.

This patient had a severe Class II skeletal pattern with a firmly retracting lower lip and a history of thumb-sucking. The upper incisors were proclined were inserted for further overjet reduction with apical control, using both Class II traction and extra-oral anchorage. As the lower incisors were severely retroclined originally, owing to the thumb-sucking habit, it was thought that some proclination of the lower incisors could be tolerated. The final result shows a

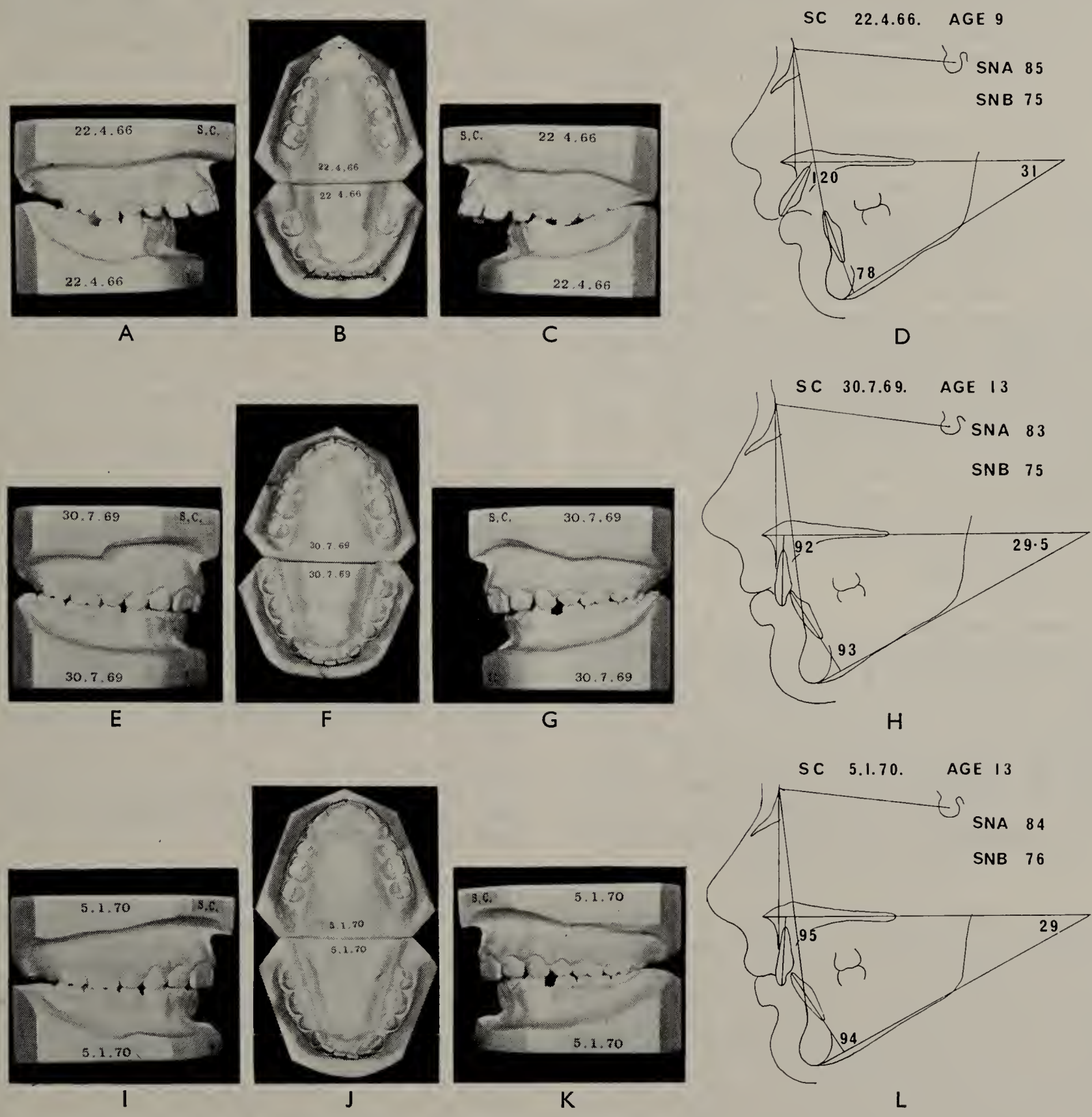


Fig. 21.—*Case* 4.

to 120° and the lowers retroclined at 78°. The overjet was increased to 18 mm. and the overbite slightly increased and incomplete. The molar relationship was a full unit Class II.

The extraction of the first premolars was followed by the insertion of fixed space maintainers, awaiting the eruption of the canines. The patient did not show the best co-operation, but upper removable appliances to retract the upper canines and then the upper incisors were used for 11 months, supported by extra-oral anchorage. Lower and upper fixed appliances lower incisor angle of 94° to the mandibular plane—an increase of 16°. After 6 months of fixed appliances the oral hygiene was dangerously poor. Although the lower left first premolar space should have been further reduced, since the tooth relationship was acceptable fixed appliances were withdrawn and replaced by a full-time removable retainer for 3 months, then worn nocturnally for 8 months.

The final models (*Fig*. 21 I, J, K) show the results 6 months after the end of retention. Active treatment took 17 months, followed by 11 months' retention.

SUMMARY

A comprehensive technique has been described for the treatment of malocclusion with a relatively severe Class II, division 1 incisor relationship, this procedure having evolved during the last 20 years of postgraduate teaching at the Eastman Dental Hospital, London.

The diagnosis involved in such cases has not been discussed, it being assumed that the extraction of all four first premolars at least was thought necessary.

The use of a simple upper removable appliance supported by extra-oral anchorage to retract the maxillary canines and to reduce the overbite has been described. Lower and upper fixed appliances were gradually assembled and inserted, with archwires, round in cross-section, running through Siamese Edgewise brackets. Space-closing loops were used to provide lower arch intramaxillary traction, and elastics were required to produce Class II traction, the anchorage being reinforced at night when necessary.

Case histories have been presented, highlighting the use of the upper fixed appliance to limit the tipping of the maxillary incisors during overjet reduction, whilst the lower appliance was used to promote and maintain incisor overbite reduction and to provide some anchorage to the upper arch.

Acknowledgements

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AN ANALYSIS OF BROKEN REMOVABLE APPLIANCES

DOUGLAS MUNNS, V.R.D., L.D.S.

Orthodontic Department, Worcester Royal Infirmary, Worcester

It is always annoying when a patient or parent reports that an orthodontic appliance has been broken, for not only will treatment time be prolonged but some relapse may result, especially if the appliance has to be sent away for repair. Consequently it was decided several years ago to initiate an investigation to ascertain whether steps could be taken to minimize such breakages. Whilst undoubtedly the mishandling of an appliance by a patient is a predisposing cause of breakage in many cases, there is little doubt that other factors must be considered.

Broadway (1964) and others have drawn our attention to deficiencies in appliance design. Harcourt and Munns (1967) reported that a metallurgical examination of broken orthodontic appliances revealed that damage to wires by faulty or worn pliers and by the opposing teeth can nearly always be seen on macroscopic examination of broken wire surfaces. Stresses are undoubtedly set up in wires by repeated adjustments and insertion and removal from the mouth. Also, investigations would suggest that faults do occur during the production of orthodontic wires and the use of faulty wire may result in eventual failure.

Originally it was intended to record only those cases with broken appliances, but after a pilot study it became obvious that control cases would have to be included as well. Two series of cases are therefore involved in this investigation. The first group of cases comprises 500 broken appliances, representing every broken orthodontic appliance reported to 6 clinics in hospitals in the counties of Herefordshire and Worcestershire and 1 clinic in South Birmingham—7 in all. It took about 3 years to collect these cases and they include those with fractures of the acrylic, fractures of wires (archwires, cribs, and springs), breaking down of soldered or welded joints, and lost appliances. The control series consists of 1000 consecutive orthodontic appliances fitted for patients in 2 of these hospitals over a very similar period, limited by the time it took to complete the thousandth case. ' Control series ' is perhaps not an entirely accurate term but is used throughout this report as no better description for this second series can be found.

Lost Appliances

Appliances are sometimes lost in circumstances where the patient is not really to blame, for example, mal de mer, but more often than not it is due to complete carelessness, such as wearing the plate in the pocket instead of the mouth, or leaving it on the tablecloth and either ' Granny tipped it away with the crumbs ', or ' the dog ate it '!! However, some of the blame for not wearing appliances can, in certain cases, be attributed to its design, a factor which has been stressed by Broadway (1964) and others. In the broken appliance series 10·6 per cent of appliances were lost, not broken, and these cases are not included in the analysis of our findings. This leaves 447 cases with broken appliances.

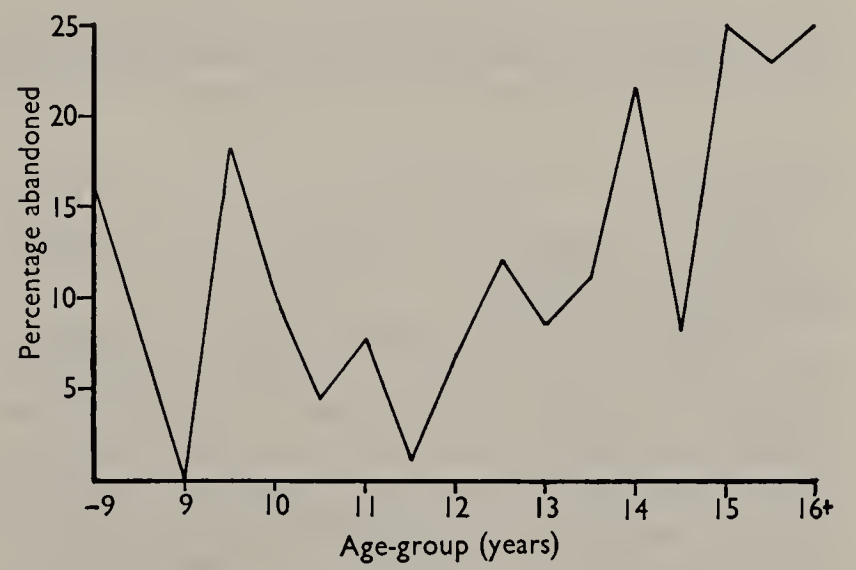


Fig. 1.—The age distribution of abandoned cases in the control series.

Abandoned Cases

In the control series 2·5 per cent of the patients moved from the district whilst wearing the appliance under review, and 11 per cent had to be abandoned through lack of co-operation, failure to attend, and similar reasons. The combined total percentages of such cases is shown in *Fig.* 1 in which the age range is divided into 6-monthly

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steps from 9 years to 16 years. Fortunately, the risk of lack of co-operation is less for the ages where the greatest number of patients are under treatment, namely, between 10 and 13 years. Forty per cent of the abandoned cases had a history of repeated broken appliances, whereas the actual incidence of broken appliances throughout the control series was 15 per cent. Setting aside these abandoned cases leaves 846 control cases on which the remaining findings are based.

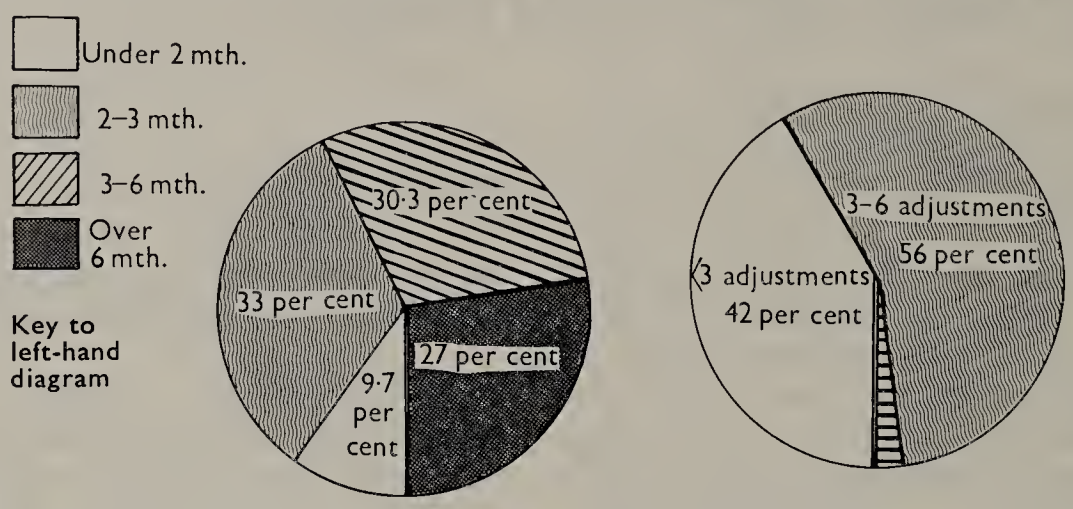


Fig. 2.—The breakage rate (*left*) and the adjustment rate before breakage (*right*) for finger-springs in the broken appliance series.

FINDINGS

Two important facts emerge from a general survey of the findings:—

1. There is the 'persistent appliance breaker' who somehow succeeds in wrecking any appliance that is inserted in the mouth. In the broken appliance group it was found that 42·1 per cent had a history of more than 1 previous breakage and of these 18·7 per cent had a history of 3 broken appliances, 4·5 per cent 4 broken appliances, and 2·3 per cent 5 or more broken appliances. It is therefore important that these patients be diagnosed early and only very limited appliance therapy provided for them.

2. The shorter the period an appliance is worn the less likely it is to be broken—an obvious fact but is it always considered when deciding on the fitting of a new appliance? One-third of the breakages occurred within 3 months of the appliance being fitted and three-fifths within 6 months.

Finger-springs

The most common tooth mover on removable appliances must be the simple finger-spring and 40 per cent of the control series cases had such springs fitted and 30 per cent of breakages were of this type of spring. In the broken appliance series 73 per cent of the finger-springs were broken within 6 months of the appliance being fitted, and from the left-hand circle of *Fig.* 2 it will be seen that over half of these were broken within the first 3 months. As stresses are undoubtedly set up in wires by repeated adjustments and insertion and removal of the appliance from the mouth an attempt was also made to ascertain the number of times that a spring was adjusted by the operator before fracture occurred. It will be seen from the right-hand circle of *Fig.* 2 that about half the fractures occurred after only very few adjustments and that nearly all the wires had fractured by the time the sixth adjustment was made. If appliances are removed from the mouth for cleaning after every meal and immediately reinserted (2 movements of the spring each time) this would amount to about 100 flexions of the spring each week, at which rate, according to the laboratory findings of Bass and Stephens (1970), the average spring should not fracture until the appliance has been worn for a year. It must, of course, be borne in mind that the experimental springs of Bass and Stephens (1970) were straight springs nearly all made with a spring-forming machine, whereas all springs in this report were, of necessity, subjected to additional strains and stresses during construction in order to conform to the contour of the palate and alveolar ridge and to fit snugly around the tooth of the patient.

Table I.—Analysis of the Various Types of Breakages (Broken Appliance Series)

Type of Breakage	*Percentage of Total Breakages*
Finger-springs	30
Cribs	36
Labial archwires	13
Acrylic fractures	12
Other breakages	9

Cribs and Archwires

Table I records for the broken appliance series an analysis of the various common types of breakages, from which it can be seen that Adam's cribs account for 36 per cent of the total. *Fig.* 3 shows the breakage rate and adjustment rate before breakage for Adams cribs, of which 60 per cent were broken within 6 months of the appliance being fitted. Similar results were found with simple archwires (67 per cent were

broken in the first 6 months) and acrylic fractures (72 per cent) although many of these acrylic fractures were due to definite carelessness of the patient, such as dropping the appliance and treading on it, and rarely occurred whilst the appliance was being worn in the mouth. It is of interest to note that there appears to be a far greater risk of breakage of cribs on the right-hand side than on the left (57 per cent: 43 per cent), and the mode of insertion and removal of appliances from the mouth may be a significant factor.

The problem of the persistent appliance wrecker is again emphasized when one considers breakages to individual parts of an appliance. *Table II* shows the percentages for various types of breakages in cases with a history of a similar previous breakage. The average for the four types of breakages was 42·6 per cent and it will be seen that the labial archwire is the most vulnerable part. The susceptibility of right-hand springs and cribs to fracture as compared with those on the left side is confirmed.

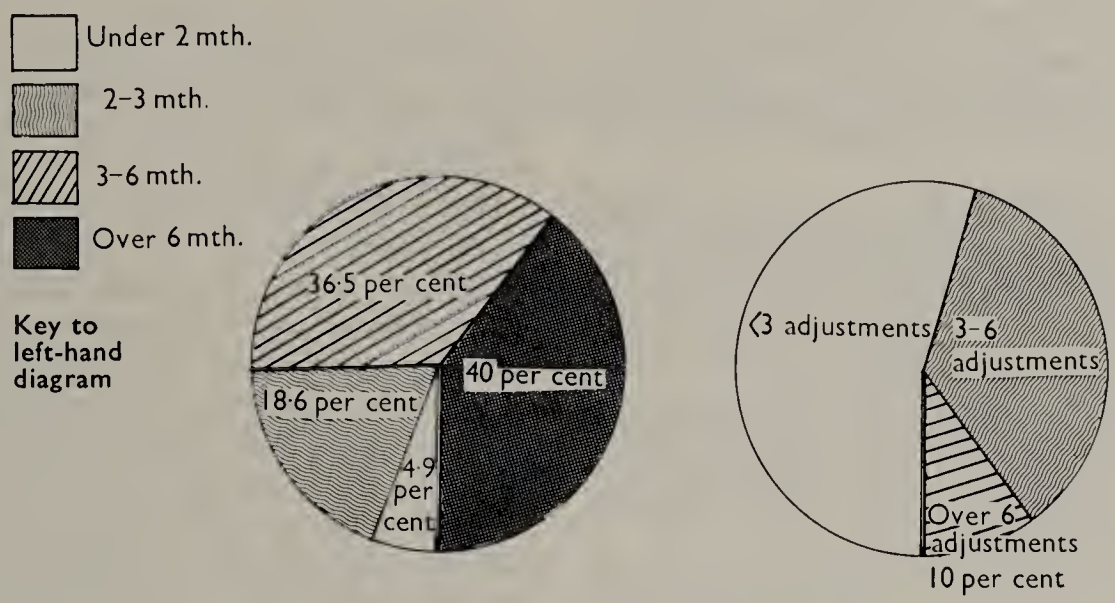


Fig. 3.—The breakage rate (*left*) and the adjustment rate before breakage (*right*) for cribs in the broken appliance series.

Table II.—Analysis of Various Types of Breakages in Cases with a History of a Previous Breakage (Broken Appliance Series)

Type of Breakage	*Percentage of Total Breakages*
Finger-springs	
Left	28·9
Right	46·9
Cribs	
Left	32·4
Right	43·4
Labial archwires	55·3
Acrylic fractures	48·7

Table III.—Percentage of Appliances recorded in each Series

Type of Appliance	*Control series (per cent)*	*Broken Appliances (per cent)*
Springs		
Box type	35·2	43·4
Open type	5·2	3·4
Screws		
With molar blocks	9·1	3·1
Without molar blocks	8·1	2·2
Tied expansion	2·7	3·4
Archwire		
0·7-mm. Simple bow	9·3	10·1
0·9-mm. Bow with auxiliary archwire	10·4	9·4
Other appliances	20·4	25·0

Complete Appliances

Finally, breakages in individual types of appliances present some interesting problems (*Table III*). The most common type of removable appliance is that using simple finger-springs to retract canines or premolars, and these are constructed either with the springs boxed over with acrylic or with no covering over the spring but with a guard-wire guiding both the action of the spring and the movement of the tooth. In our series, although many more of the former than the latter type of appliance were recorded, it would appear that there may be a greater risk of spring fracture in the box type of appliance than in the open-guard type.

The open-guard type of appliance is, of course, preferable to the closed-box type for the health of the gingivae, but its use is not always practicable. There seems little doubt that one reason for the fracture of the springs in the boxed-in type of appliance is initial mutilation of the spring by the patient when attempting to cleanse the box of food particles, often using various gadgets other than the toothbrush in the process.

To prevent space closure closed-box, and open-guard appliances are often fitted just before teeth are extracted or immediately afterwards (with the impression being taken prior to the operation), and of these two types of appliances which subsequently were broken, 18 per cent

had teeth extracted after the fitting of the appliance and 17 per cent had teeth extracted immediately before the fitting so that the timing of the extraction has little effect on the liability to breakage. It is worth observing, however, that fractures of cribs are doubled where extractions are undertaken after an appliance has been fitted.

Three types of appliances incorporating a screw are in regular use, the screws used being those described by Haynes and Jackson (1962):—

1. The covered molar appliance designed to move one or more incisors forward over the bite, a Hawley Russell Schwartz pattern 999 screw normally being used.

2. A Schwartz appliance without molar blocks incorporating a screw to move one or more teeth in the buccal segment distally (Shaw and Edmondson, 1962), with or without extra-oral anchorage. A Glenross small screw is used.

3. A non-parallel ' expansion ' appliance (Shaw and Edmondson, 1962) tied at the posterior border to increase the intercanine width, an Ash Badcock upper screw being used.

The incidence of breakage in the first two of these appliances is less than in any of the other types of appliances recorded, and statistics show that the screw itself is not the weak part of the appliance; broken cribs feature in some 40 per cent of these breakages. The length of time that the appliance is worn obviously contributes to the risk of fracture, for whereas treatment for 66 per cent of type 1 and 43 per cent of type 2 wearers was completed in less than 6 months, treatment for only 23 per cent of type 3 wearers was completed within the same period.

Two other very similar types of appliances are regularly used. One has two cribs on the posterior teeth and a simple labial archwire, such as would be used as a space maintainer or a retention appliance, and the other is of a similar design but with thicker archwire (0·9 mm. instead of 0·7 mm.) and a sprung auxiliary sliding archwire for retracting incisors (the twin-bow appliance) Dickson (1964). In the broken appliance series there was, as would be expected, far less risk of the thicker archwire fracturing, although there was a fairly high breakage rate of the more delicate secondary archwire. However, the final analysis reveals that the incidence of breakages in the second appliance was less than that for the first, although admittedly there was only a small margin between them. The duration of time worn was approximately the same for both appliances: 11·1 and 12·7 months respectively.

Other types of appliances could be compared in a similar manner if the investigation had been continued to include sufficient numbers for such comparisons. However, as there were less than 2 per cent of appliances in each of the other categories the publication of figures would be misleading. The vulnerable types of appliances would seem to be those types where the spring is boxed in, e.g., Z or flapper springs of various types, and those where a soldered or welded joint is used, e.g., where an archwire is soldered or welded to a first molar crib. Appliances that are only worn at night, such as the Activator, have the best prognosis.

CONCLUSION

A far greater number of breakages would have to be investigated to provide a complete analysis for all types of appliances in general use, but even so we shall always have with us the persistent appliance wrecker and early diagnosis of such cases and removal from appliance treatment lists would seem to be essential. The operator can, however, reduce the risk of appliance breakage to a minimum by precise timing of appliance therapy and careful selection of appliance design, by reducing adjustments of cribs and springs to a minimum, and by giving careful instruction to the patient in the art of inserting and removing the appliance from the mouth and regular cleansing. The technician constructing the appliance can assist by reducing wire manipulation to a minimum, by renewing worn pliers, and by taking great care to avoid damage to wires during finishing and polishing. The efforts of both operator and technician will be in vain if the patient does not take proper care of the appliance and does not abide by the instructions given by the operator and those printed on the instruction sheet.

SUMMARY

An investigation into the causes and effects of broken appliances has been described and statistical results have been enumerated.

Acknowledgements

I am most grateful to all those who have made this investigation possible; my colleagues in the Birmingham Region for their advice and assistance, the Birmingham Regional Hospital Board for a grant towards the project, and their senior statistician, Miss M. Wall, for her untiring co-operation in extracting statistics from information provided. I am also grateful for clerical assistance at various hospitals in the region.

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RESORPTION OF UPPER INCISORS FOLLOWING ORTHODONTIC TREATMENT

P. H. MORSE, L.D.S., D.Orth. R.C.S. (Eng.), F.D.S. R.C.S. (Edin.)*

Senior Registrar, Orthodontic Department, Eastman Dental Hospital, London

INTRODUCTION AND REVIEW OF THE LITERATURE

ORTHODONTIC treatment has been held responsible for many resorbed teeth. Quotations such as ' half the patients with resorbed teeth had undergone orthodontic treatment ' (Kramer, 1969) have made orthodontists themselves very apprehensive with regard to the possible effects of their ministrations. Many possible aetiological factors have been cited. In an excellent study Phillips (1955) found no correlation between the degree of resorption and such factors as sex, age at the start of orthodontic treatment, length or method of orthodontic treatment, or the amount of orthodontic treatment involved. He suggested a metabolic factor in the extreme cases although documentation was insufficient and stated: ' this metabolic factor (dietary or endocrine) may also account for individual variations '. There is, however, no scientific proof of this (Winter, 1969). Phillips (1955) also suggested that injured teeth are more liable to resorption and felt that possibly, in some cases, deflexion of Hertwig's sheath produces a loss of potential root length. This would, he felt, account for those teeth whose apices had a resorbed appearance yet no actual loss of root length from measurement of pre- and post-orthodontic treatment radiographs. This is unlikely, however, as trauma rarely, if ever, involves all the upper incisors, or even the central incisors, equally (Winter, 1969).

The first recorded reference to resorption is by Bates (1856). There were then varying reports in the literature and much concern following Ketcham's articles (1927 and 1929), which were contemporaneous with the widespread use of dental radiography. Hellman (1930) found that the type of appliance is not important but that the manner of use *is* important. Rudolph (1936), in a series of 439 orthodontically treated patients (209 males and 230 females), found 304 cases of resorption (69 per cent). The resorption cases comprised 65 per cent of males and 73 per cent of females. In a control series with an age range of 7 to 79 years there were 739 cases aged from 7 to 21 years (i.e., orthodontic age-group). Of these, 38 (5·14 per cent) had resorption. No resorption was noted in any patient below 13 years. Rudolph found that resorption occurred with decreasing frequency in upper lateral incisors, upper central incisors, lower central incisors, lower lateral incisors, upper canines, lower first molars, lower canines, upper first molars, upper premolars and lower premolars.

Oppenheim (1944) stated that a certain degree of damage to bone, cementum, periodontal tissues, and pulp is unavoidable during orthodontic treatment. In order to reduce this unavoidable damage, orthodontic forces should be gentle, elastic, intermittent, and well directioned. Oppenheim believed that cementum resorption is always present, though not necessarily at the apex, in orthodontic procedures. Over 90 per cent of teeth examined by Henry and Weinmann (1951) showed histological root resorption. Those with the greatest amount of resorption before treatment had the greatest amount after treatment. Massler and Perreault (1954) found a tendency to resorption in almost all the permanent teeth examined. This varied in different individuals and in different teeth in the same individual and was greater in females. Massler and Malone (1954) examined radiographs of 708 people of 12 to 49 years who had never had orthodontic treatment. Each individual had one or more teeth with some degree of resorption; in decreasing order of frequency resorption occurred in lower incisors, upper lateral incisors, premolars, upper central incisors, and canines. Of the orthodontically treated teeth, 93 per cent showed some resorption; moderate (2–4 mm.) in 31 per cent, severe (4 mm. to half-root length) in 10·8 per cent, and very severe (greater than half-root length) in 3·4 per cent.

The general view today follows that of Hemley (1941) who stated that with careful control of appliances and periodic radiographs the amount of root loss following orthodontic treatment does not reduce the life span of the teeth concerned (confirmed by Strahan, 1969).

* Present appointment: Consultant Orthodontist, Orthodontic Unit, Booth Hall (Children's) Hospital, Charlestown Road, Blackley, Manchester 9.

Presented at the Scottish Meeting held on 23 October, 1970.

PRESENT INVESTIGATION

This investigation was stimulated by a case in which radiographs showed resorption of the upper central incisor roots following orthodontic treatment (*Fig.* 1). This patient had a poor periodontal condition and in view of this the original hypothesis suggested a poor response to trauma of any kind. In fact there were a number of other possible aetiological factors:—

1. An incomplete overbite.
2. Gross lip incompetence with an increased lower facial height.
3. There was a slight relapse of overjet following cessation of retention. This would suggest an anterior oral seal habitually produced by the contact of the tongue against the lower lip (*Figs.* 2, 3).

Almost certainly the upper incisors were not under lower lip control at the end of orthodontic treatment. From measurements of the patient's lateral skull radiographs it was found that 4 mm. of resorption had occurred during active treatment and a further 1 mm. during retention with a removable appliance. This case was not treated by following the criteria of Ballard (1967) and it is possible that the upper labial segment would have remained stable had the lower incisors been depressed to the occlusal line and retracted a shade prior to overjet reduction.

There was no question of poor patient co-operation in this case since the overjet was reduced using a fixed appliance and the intramaxillary traction was activated by the operator. Thus, there was no possibility of the force applied being intermittent.

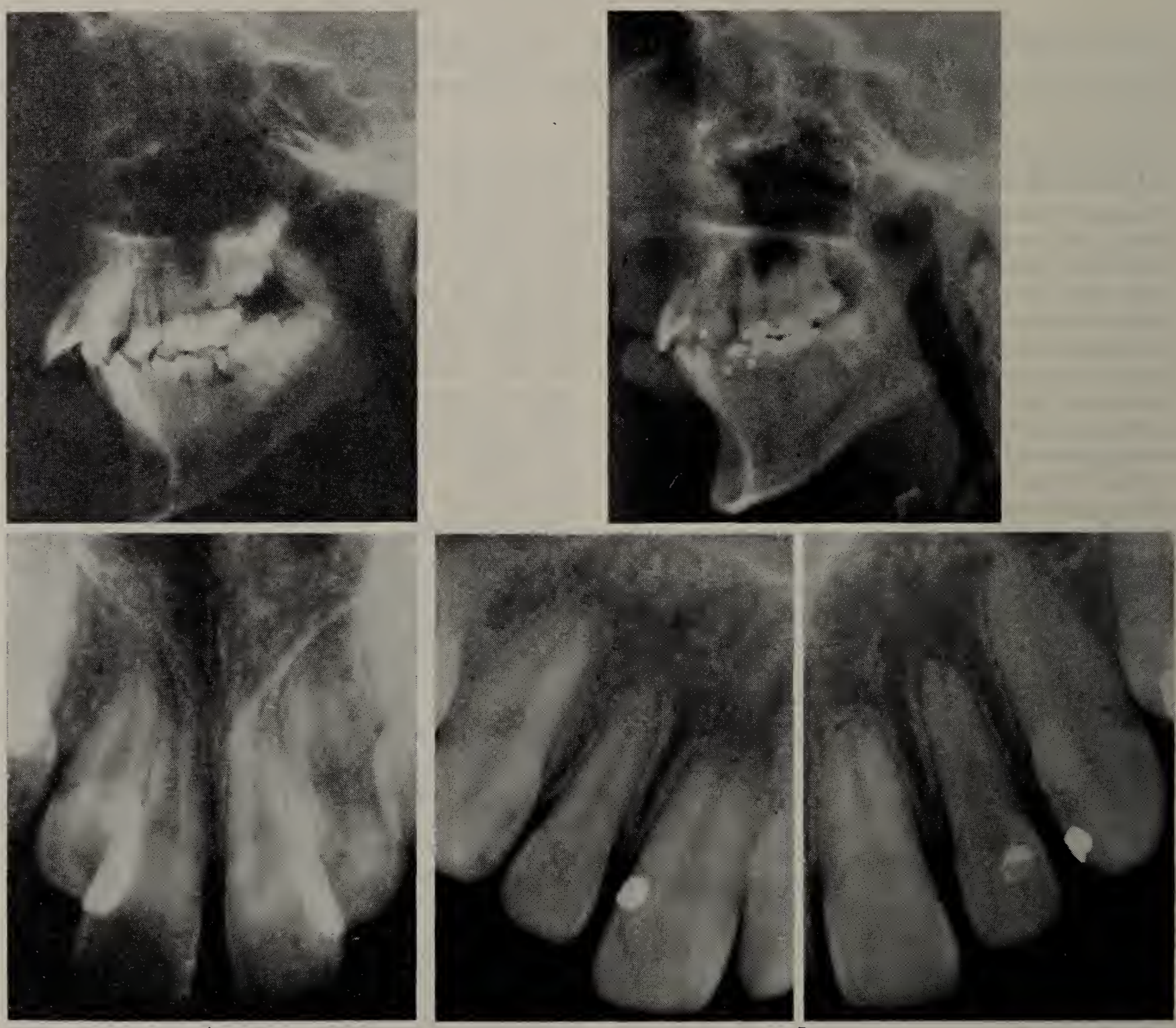


Fig. 1.—Radiographs of a patient with resorption of the upper incisor roots. A, Before treatment. B, Nine months after cessation of retention.



A B

Fig. 2.—Profile and full-face photographs of the patient shown in *Fig.* 1. A, Before treatment (note the poor periodontal condition). B, After treatment.



A B

Fig. 3.—Right views of models of the patient shown in *Figs.* 1 and 2. A, Before treatment. B, After treatment.

MATERIAL

Four groups of patient records were studied:—

1. Group A, Resorption Cases

On punch cards filled out for completed cases 40 cases were found for whom the entry ' resorption ' had been marked either as a result of a comment by the consultant dismissing the patient or the senior registrar completing the punch card.

2. Group B, Orthodontic Controls

Twenty-five alphabetically consecutive, completed orthodontic cases with full records were investigated to establish a set of average values for patients undergoing orthodontic treatment.

3. Group C, Non-orthodontic Controls

Lateral skull radiographs of 20 individuals who had had no orthodontic treatment were investigated. Lateral skull radiographs had been taken at 14 and 19 years in each patient. It was thus possible to measure any spontaneous changes occurring in non-treatment cases.

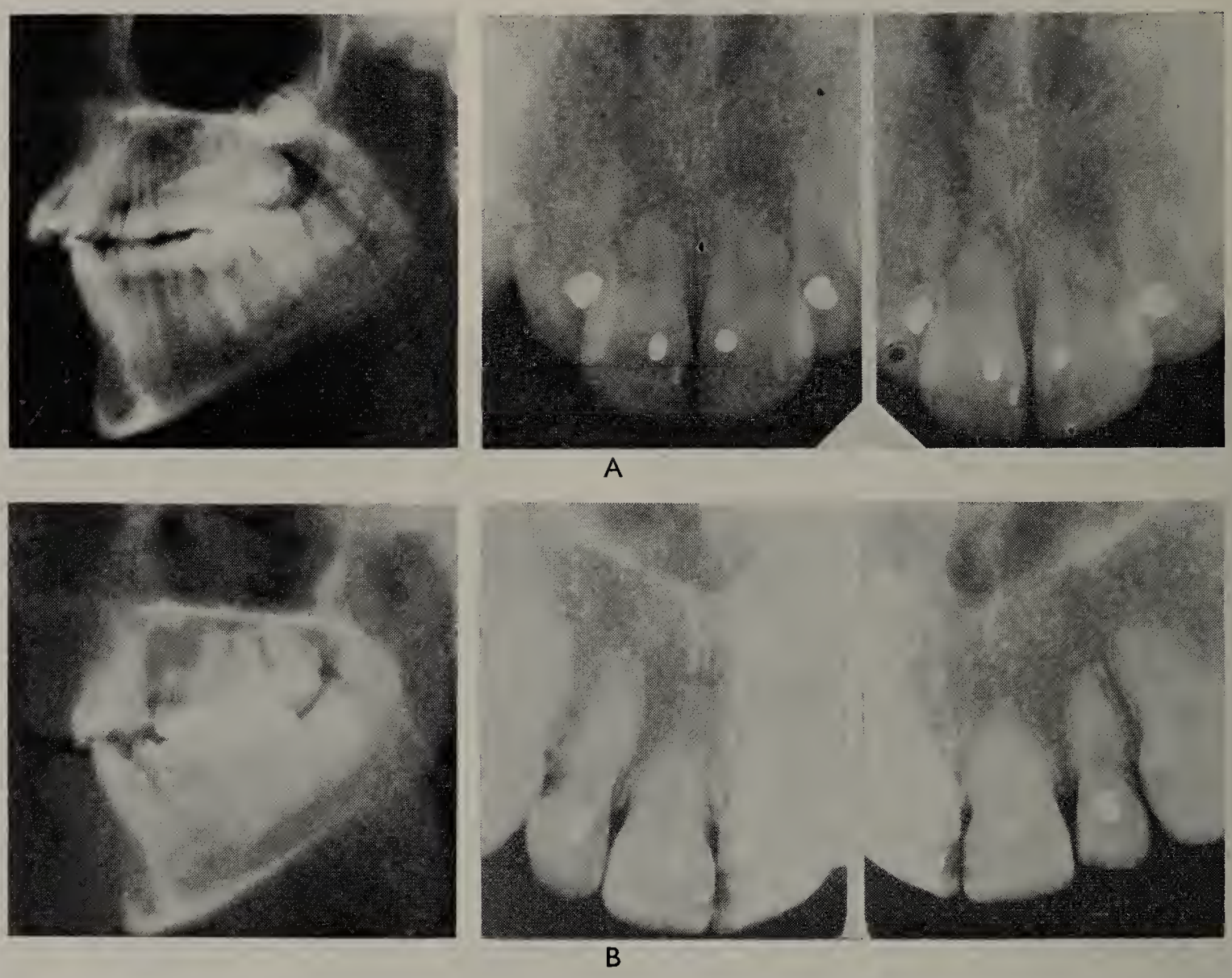


Fig. 4.—Radiographs of a patient with a resorbed appearance of the upper incisors prior to orthodontic treatment. From measurements of pre- and post-treatment lateral skull radiographs, it was found that no resorption had occurred. A, Before treatment. B, After treatment.

The length of the upper incisors from the lateral skull radiographs is not automatically measured and therefore small amounts of resorption may not have been noted. In addition, intra-oral radiographs of anterior or posterior teeth are not routinely taken at the beginning or end of treatment.

Of these 40 cases, 6 were discarded as no resorption had in fact occurred when checked by measurement of pre- and post-treatment lateral skull radiographs. One example of these discarded cases is shown in *Fig*. 4.

Subgroup A

This subgroup comprised 11 cases from group A with above average resorption (3 mm. or more).

4. Group D, Class II, Division 2 Cases

A Class II, division 2 series of cases was investigated because a suggested aetiological factor in resorption of upper incisor apices is the closeness of the upper incisor apices to the upper labial plate. Since the upper central incisors apices tend to be close to the labial plate in all Class II, division 2 malocclusions, 25 consecutive, completed, Class II, division 2 cases were investigated only to ascertain whether the average root length of the upper incisors *prior* to treatment differed from that in the other groups (*Fig*. 5).

METHOD

The length of the upper incisors was measured to the nearest $\frac{1}{2}$ mm. on lateral skull radiographs, using a sliding gauge (J. Rabone and Sons, No. 1466).

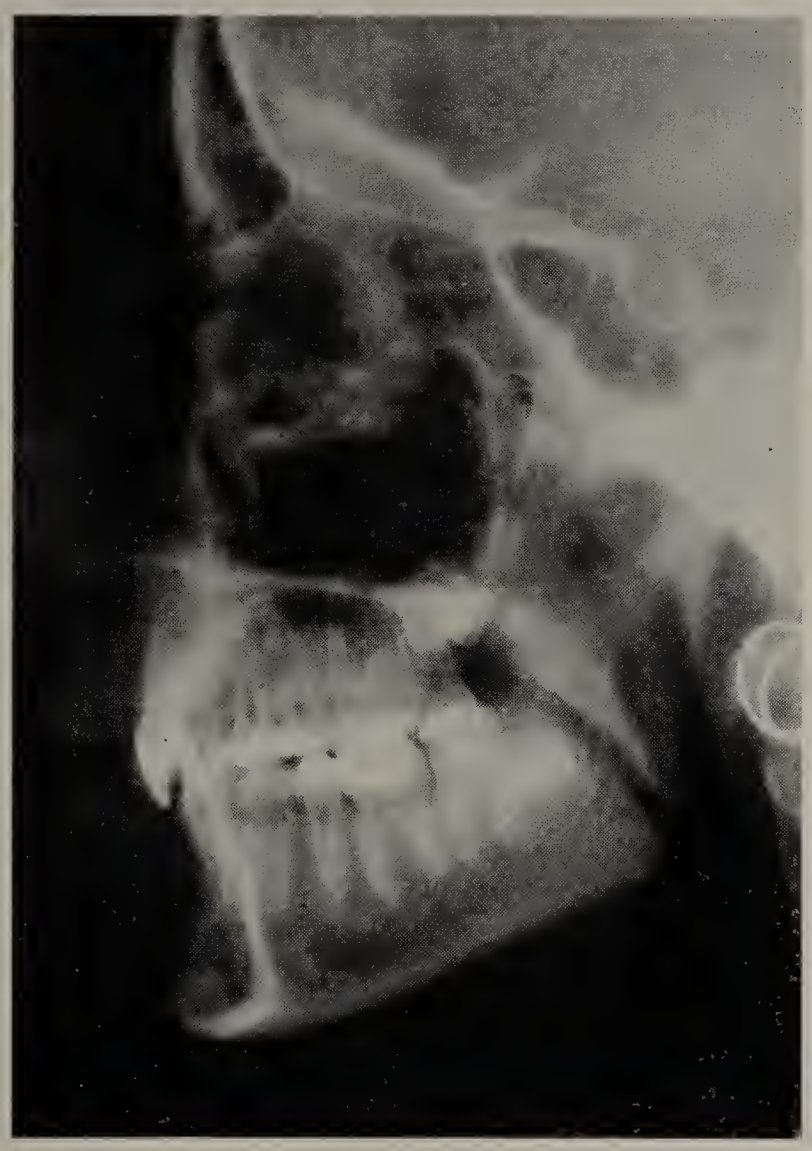


Fig. 5.—Lateral skull radiograph of a patient with a Class II, division 2 malocclusion. Note the closeness of the upper incisor apices to the upper labial plate.

RESULTS

The results are shown in *Tables I–IV*.

Sex Incidence

A greater preponderance of females was found in group A (resorption cases) than in group B (orthodontic controls). This is contrary to the findings of Phillips (1955) but agrees with Rudolph (1936). This preponderance of females is *not* statistically significant (*see Table I*).

Age

The average age at institution of treatment was substantially greater in the resorption cases (13·50 years) than in the orthodontic controls (11·61 years). The average age at institution of treatment in group A females was 13·4 years and in group A males 13·67 years. Since the adolescent spurt in growth occurs, on average at 12–13 years in females and at 14–15 years in males (Tanner, 1962) it would seem that these pubertal changes play no part in the aetiology of the resorption of upper incisors in *females*. However, treatment usually was completed by 15·48 years. Treatment to $\underline{21|12}$ was therefore contemporaneous with the *male* pubertal growth spurt.

The peak of group A cases occurs at 13 years and group B at 12 years (*Fig.* 6). The difference between average age at institution of treatment in group A compared with group B was statistically significant at the 5 per cent level (*Table I*).

Length of Treatment

The overall average length of treatment was greater in group A and subgroup A than in group B. Also, the overall average length of treatment to $\underline{21|12}$ was greater in group A than group B. However, in subgroup A, with more severe resorption, the overall average length of treatment to $\underline{21|12}$ was less than in groups A and B. This would suggest that if the length of treatment to $\underline{21|12}$ is a factor in the aetiology of root resorption it is only so in the *less* severe resorptions. The difference in treatment duration between the groups was *not* statistically significant (*Table I*).

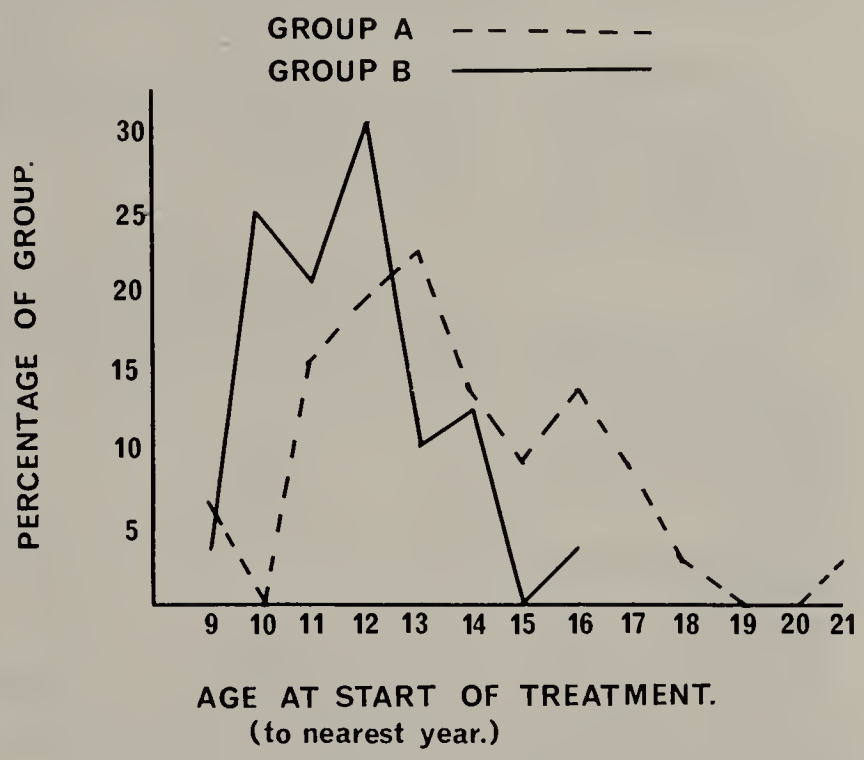


Fig. 6.—A frequency distribution graph comparing groups A and B. Note that the peak of group B is at 12 years, and that of group A is at 13 years.

Incisor Classification

There were substantially more Class II, division 1 incisor relationships in group A (74 per cent) than in group B (60 per cent). Indeed, in subgroup A there were 91 per cent Class II, division 1 incisor relationships. In group C (non-orthodontic controls) there were only 15 per cent Class II, division 1 incisor relationships. The increased incidence of Class II, division 1 malocclusions is not statistically significant in group A as

compared to group B, but it is just significant at the 5 per cent level comparing subgroup A to group B (*Table II*).

Skeletal Pattern

Little difference occurred between the distributions of Class I, II, or III skeletal patterns in group A, subgroup A, or group B. In group C there was only approximately half the incidence of Class II skeletal patterns as compared with the other groups. Group C are not, of course, malocclusions! Group A skeletal patterns are not statistically significantly different from group B (*Table II*).

Maxillary-mandibular-plane Angle

There was little difference between the average maxillary-mandibular-plane angles in group A, subgroup A, or group B. The average maxillary-mandibular-plane angle in group C at age 14 years was lower (26·65°) than in the other groups and it had decreased by an average of just more than 1° by 19 years (25·43°) (*Table II*).

Angulation of $\underline{1|1}$ to the Maxillary Plane

The average angulation of $\underline{1|1}$ to the maxillary plane before orthodontic treatment was begun in group A (116·41°) and subgroup A (118·45°) was greater than in group B (112·58°). Since the average angulations after treatment were very similar in all these groups the average angular reduction as a result of treatment was correspondingly greater in group A and subgroup A. Little spontaneous change occurred in group C between 14 years (average 109·88°) and 19 years (average 110°) (*Table II*).

Table I.—Age, Sex, and Length of Treatment of Three Groups of Patients studied for Resorption

Feature	Group A (Resorption Cases)	Subgroup A (Above-average Resorption)	Group B (Orthodontic Controls)	Group C (Non-orthodontic Controls)
No. in group	34	11	25	20
Sex incidence				
Male	13 (38·24 per cent)	4 (36·36 per cent)	12 (48 per cent)	8 (40 per cent)
Female	21 (61·76 per cent)	7 (63·64 per cent)	13 (52 per cent)	12 (60 per cent)
Age (in years) at start of treatment				
Average	13·50*	13·22	11·61*	No treatment
S.D.	3·94		1·59	
Range	9 to 20·67	9·25 to 18·17	8·67 to 15·58	
Age (in years) at end of treatment				
Average	15·48	15·20	13·49	
S.D.	3·34		1·69	
Range	11·5 to 24·33	12·17 to 17·25	9·17 to 17·5	
Length of treatment in months				
Overall				
Average	23·65	23·82	20·96	No treatment
S.D.	11·95		9·4	
Range	49 to 9	32 to 9	48 to 6	
To $\underline{21\|12}$				
Average	11·85	9·36	10·64	
S.D.	9·67		2·026	
Range	43 to 4	27 to 5	25 to 0	
Excluding no treatment to $\underline{21\|12}$				
Average	13·43	10·3	11·56	
S.D.	9·19			

* Statistically significant

Soft Tissues

Lips

There was little difference in the percentage incidence of cases diagnosed as having incompetent lips between group A (85 per cent) and group B (88 per cent). However, in subgroup A all 11 cases were diagnosed as having incompetent lips (100 per cent).

Tongue to Lower Lip Anterior Oral Seal

There was a much greater incidence of cases diagnosed as having tongue to lower lip

anterior oral seals in subgroup A (63·64 per cent) compared with group A (47·1 per cent) and group B (44 per cent). One case in subgroup A possibly had an endogenous tongue thrust (Ballard, 1962). There is no statistical significance in these findings (*Table III*).

In group C (non-orthodontic controls) 6 out of 20 cases (30 per cent) were diagnosed as having competent lips and 14 out of 20 (70 per cent) as having incompetent lips. Walther (1960), in a much larger survey, found the incidence of competent lips to be 18 per cent and incompetent lips 82 per cent.

Table II.—Incisor Classification, Skeletal Pattern, Maxillary-mandibular-plane Angle, and Angulation of $\underline{1|1}$ to the Maxillary Plane in Three Groups of Patients studied for Resorption

Feature	Group A (Resorption Cases)	Subgroup A (Above-average Resorption)	Group B (Orthodontic Controls)	Group C (Non-orthodontic Controls)
Incisor classification				
I	6 (17·65 per cent)	1 (9·1 per cent)	5 (20 per cent)	13 (65 per cent)
II, Division 1	25 (73·53 per cent)	10 (90·9 per cent)*	15 (60 per cent)*	3 (15 per cent)
II, Division 2	2 (5·88 per cent)		4 (16 per cent)	1 (5 per cent)
III	1 (2·94 per cent)		1 (4 per cent)	I–III 2 (10 per cent) III 1 (5 per cent)
Skeletal pattern				
I	5 (14·7 per cent)	2 (18·18 per cent)	5 (20 per cent)	8 (40 per cent)
II	25 (73·53 per cent)	8 (72·73 per cent)	18 (72 per cent)	7 (35 per cent)
III	4 (11·76 per cent)	1 (9·1 per cent)	2 (8 per cent)	5 (25 per cent) I+mild II + mild III=90 per cent
Maxillary-mandibular-plane angle				
Average	29·07°	31·18°	30·08°	14 yr. 26·65° 35·5 °to 21°
Range	40° to 14°	37° to 24°	46° to 20°	19 yr. 25·43° 34° to 20°
Angulation of $\underline{1\|1}$ to maxillary plane				
Before treatment				
Average	116·41°	118·45°	112·58°	14 yr. 109·88°
Standard deviation	9·12°		8·54°	
Range	134 to 97·5°	126° to 109°	130 to 96°	120° to 100·5°
After treatment				
Average	100·49°	100·36°	101·72°	19 yr. 110°
Standard deviation	8·38°		7·24°	
Range	120 to 83°	110° to 94°	117 to 89·5°	122° to 100·5°

*Statistically significant

Overjet and Relapse

There was a greater incidence of increased overjet in group A (87·5 per cent) and subgroup A (100 per cent) than in group B (76 per cent). The average overjet dimensions were greater before treatment in group A than in group B as was the average overjet reduction, the average overjet relapse following cessation of retention and also the number of patients who suffered some relapse after the end of retention. There were no total relapses of overjet in group B but of those in group A who had overjet reduction as part of their orthodontic treatment, 3 out of 22 (13·64 per cent) relapsed completely (this does not include 1 patient who failed a recall appointment and whose overjet was relapsing shortly after cessation of treatment). The difference between the overjet dimensions at the start of treatment in group A as compared with group B was significant at the 5 per cent level (*Table III*).

Overbite

There were substantially more incomplete overbites in subgroup A (63·64 per cent) than in group A (41·18 per cent) or group B (48 per cent). The incidence of incomplete overbites in group C was 25 per cent. These differences are not statistically significant (*Table III*).

Orthodontic Extractions

There was little difference between groups A and B except that in group A there were 4 out

Table III.—Soft Tissues, Overjet and Relapse, and Overbite in Three Groups of Patients studied for Resorption

Feature	Group A (Resorption Cases)	Subgroup A (Above-average Resorption)	Group B (Orthodontic Controls)	Group C (Non-orthodontic Controls)
Soft tissues:				
Lips				
Competent	5 (14·71 per cent)		3 (12 per cent)	6 (30 per cent)
Incompetent	29 (85·29 per cent)	11 (100 per cent)	22 (88 per cent)	14 (70 per cent)
Tongue to lower lip anterior oral seal	16 (47·1 per cent) (including 1 ? endogenous tongue thrust)	7 (63·64 per cent) (including 1 ? endogenous tongue thrust)	11 (44 per cent)	4 (20 per cent)
Overjet				
Increased (4 mm.+)	Out of 32 cases (2 with no models) 28 (87·5 per cent)	11 (100 per cent)	19 (76 per cent)	7 (35 per cent)
Normal (2–3 mm.)	2 (6·25 per cent)		3 (12 per cent)	11 (55 per cent)
Reduced (1·5 mm. or less)	2 (6·25 per cent)		3 (12 per cent)	2 (10 per cent)
Overjet dimensions:				
Start of treatment				
Average	8·69 mm.	8·1 mm.	6·44	14 yr. 3·6 mm.
Standard deviation	3·99 mm.*		3·72 mm.*	
Range	14 to 0 mm.	14 to 4 mm.	15 to 1 mm.	8 to 1 mm.
End of treatment				
Average	3·89 mm.	3·5 mm.	2·92 mm.	19 yr. 3·45 mm.
Range	10 to 2 mm.	7 to 2 mm.	5 to 1 mm.	8 to 0 mm.
Recall	4·52 mm. (excluding 1 relapsing)	5·3 mm. (excluding permanent retention = 5·89)	3·14	
Average overjet reduction during treatment	4·94 mm.	5·6 mm.	3·52 mm.	None
Excluding no overjet reduction	7·41 mm.	6·22 mm.	5·44 mm.	
Relapse	Whole Group 31 cases / Overjet Reduction 22 cases	Whole Group 10 cases / Overjet Reduction 9 cases	Whole Group 25 cases / Overjet Reduction 17 cases	
No relapse	20 (64·52 per cent) / 11 (50 per cent)	4 (40 per cent) / 3 (33·3 per cent)	18 (72 per cent) / 10 (58·82 per cent)	
Slight (1–2 mm.)	7 (22·58 per cent) / 7 (31·82 per cent)	3 (30 per cent) / 3 (33·3 per cent)	6 (24 per cent) / 6 (35·29 per cent)	None
Partial (3–4 mm.)	1 (3·23 per cent) / 1 (4·55 per cent)	2 (20 per cent) / 2 (22·2 per cent)	1 (4 per cent) / 1 (5·88 per cent)	
Complete	3 (9·68 per cent) / 3 (13·64 per cent)	1 (10 per cent) / 1 (11·1 per cent)	None / None	
Overbite				
Complete	18 (52·94 per cent)	4 (36·36 per cent)	10 (40 per cent)	14 (70 per cent)
Incomplete	14 (41·18 per cent)	7 (63·64 per cent)	12 (48 per cent)	5 (25 per cent)
Anterior open bite	2 (5·88 per cent)	None	3 (12 per cent)	1 (5 per cent)

* Statistically significant.

of 34 (11·76 per cent) multiple extraction cases (i.e., more than 4 teeth extracted as part of orthodontic treatment). This would imply an increased difficulty of orthodontic treatment.

Appliance Therapy

Group A had more treatments with fixed appliances only (26·47 per cent) than group B (4 per cent) (*Table IV*). However in subgroup A only 9·09 per cent of treatments were with fixed appliances alone. Apical control of the upper incisors using a torquing force in the archwire during overjet reduction occurred in 29·41 per cent of group A and 27·28 per cent of subgroup A cases. In group B an apical torquing force was used in only 8 per cent of cases. The incidence of fixed appliances and apical torque was greater in group A than could be accounted for by the increased age at the commencement of treatment.

The increased incidence in group A of fixed appliances and those appliances in which a torquing force was applied to the upper incisors as compared with Group B was just statistically significant (*Table IV*).

The average amount of resorption in all group A cases during treatment was 2·18 mm. Since the average resorption during treatment in those cases in which only fixed appliances were used was 2·08 mm,, and the average resorption during treatment in those cases in which a torquing force was applied to the upper incisors was 2·17 mm., it would seem that there is little correlation between the *degree* of resorption occurring during treatment and the type of appliance used.

Table IV.—Appliances, Retention, Length of Upper Incisors and Resorption, in Four Groups of Patients studied for Resorption

Feature	Group A (Resorption Cases)	(Subgroup A) (Above-average Resorption)	Group B (Orthodontic Controls)	Group C (Non-orthodontic Controls)	Group D (Class II, division 2)
Appliances					
Removable only	6 (17·65 per cent)	2 (18·18 per cent)	2 (8 per cent)	None	
Fixed only	9 (26·47 per cent)*	1 (9·09 per cent)	1 (4 per cent)*		
Removable and fixed	19 (55·88 per cent)	8 (73·73 per cent)	19 (76 per cent)		
Apical torque	10 (29·43 per cent)*	3 (27·28 per cent)	2 (12 per cent)*		
Functional	None	None	3 (12 per cent)		
Retention					
Average	7·86 mth. (excluding 1 permanent)	7·5 mth. (excluding 1 permanent)	4·64 mth.	None	
Excluding no retention	9·21 mth.	9·38 mth.	5·04 mth.		
Range	27 to 2 mth.	27 to 2 mth.	13 to 2 mth.		
Length of upper incisors: (corrected for magnification)					
Before treatment					
Average	22·89 mm.*	23·83 mm.	24·26 mm.*	14 yr. 23·86 mm.	22·84 mm.
S.D.	2·34 mm.	2·2 mm.	1·79 mm.		
Range	27·1 to 18·69 mm.	27·1 to 19·63 mm.	28·04 to 21·5 mm.	28·04 to 18·69 mm.	26·17 to 17·76 mm.
After treatment					
Average	29·79 mm.	20·81 mm.	24·21 mm.	19 yr. 23·63 mm.	
S.D.	2·23 mm.	2·2 mm.			
Range	25·23 to 17·29 mm.	24·3 to 17·29 mm.	27·1 to 21·5 mm.	28·04 to 17·76 mm.	
Resorption					
End of treatment					
Average	2·18 mm.	2·86 mm.	1 case 1 mm.	1 case 2 mm.	
Range	4 to 0·5 mm.	4 to 1·5 mm.			
End of retention					
Average	2·08 mm.	3 mm.	1 case 1·5 mm.	2 cases 1 mm.	
Range	4 to 0·5 mm.	3·5 to 2·5 mm.			
Recall					
Average	2·73 mm.	4 mm.			
Range	5 to 0·5 mm.	5 to 3 mm.			
Overall maximum average	2·5 mm.				

* Statistically significant.

Twenty-one cases from group A had long-term recall records of their teeth (i.e., at least 2 years after retention ceased). Ten of these (48 per cent) had no increased resorption from the end of retention to recall. Eleven of the 21 (52 per cent) did have increased resorption and comprised 4 Edgewise multiband cases, 3 cases who had worn only removable appliances, and 4 who had worn both removable and fixed appliances during treatment. One of the cases who had worn both fixed and removable appliances had had an upper removable appliance and then a twin wire arch with orthodontic bands on 621|126. The right upper central incisor was traumatically placed at the end of treatment and resorption was greatly increased on this tooth; 1| was resorbed 7 mm. and |1 was resorbed 2 mm. (*Fig.* 7). Those cases with increased resorption at recall comprised an inordinately high proportion of Edgewise cases.

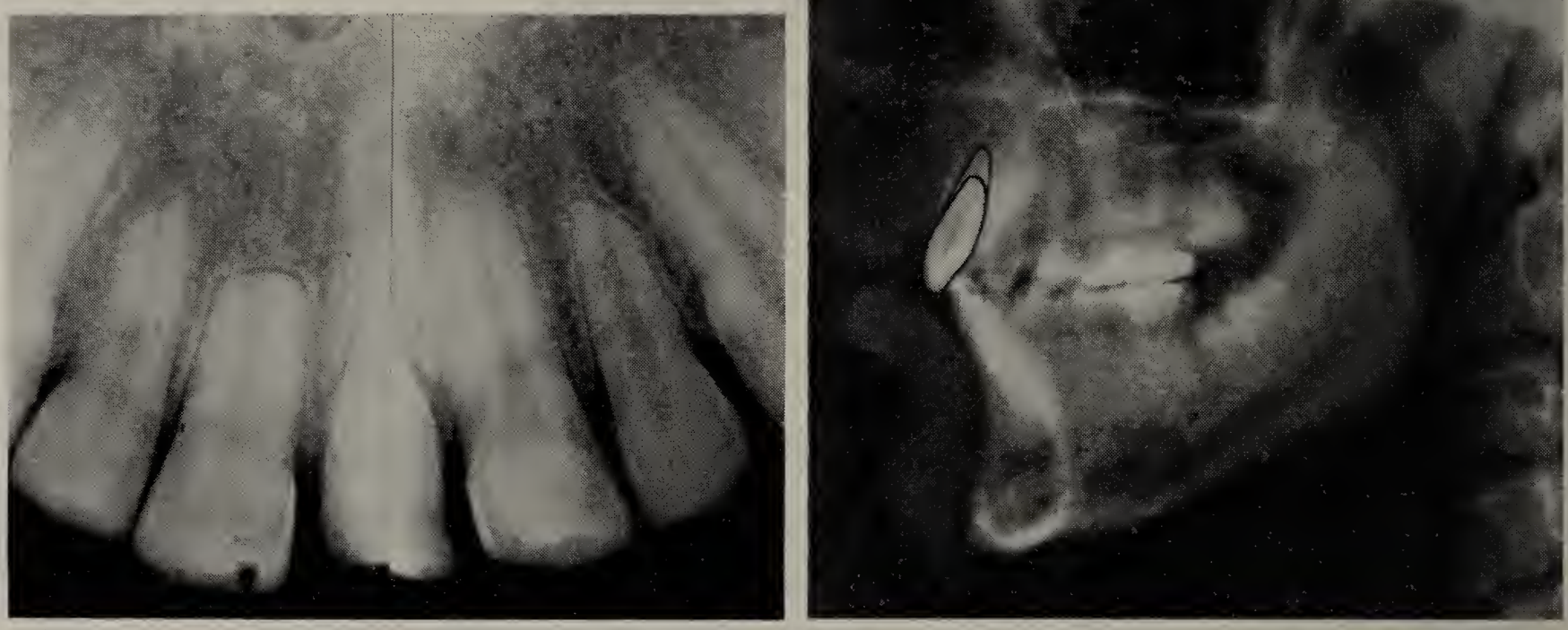


Fig. 7.—Radiographs of a patient with uneven resorption of the upper incisor roots after treatment.

Retention

The average length of retention following active appliance therapy was definitely greater in group A (all cases, average 7·86 months, excluding cases with no retention, average 9·21 months) than in group B (all cases, average 4·64 months, excluding no retention, average 5·04 months). These differences were not statistically significant (*Table IV*).

The Length of the Upper Incisors

Black (1902) gave average figures from measurements of extracted upper central incisor teeth as follows:—

	Overall	*Crown*	*Root*
Average	22·5 mm.	10 mm.	12 mm.
Greatest	27 mm.	12 mm.	16 mm.
Least	18 mm.	8 mm.	8 mm.

Since the measurements of upper central incisor teeth in this investigation were taken from lateral skull radiographs the magnification of the cephalostat was assessed and found to be 7 per cent.

Corrected figures for the original measurements are shown in *Table IV*. It will be seen that the lengths of upper central incisor teeth in group A (average 22·89 mm.) and group D (average 22·84 mm.) are very similar and somewhat less than in group B (average 24·26 mm.). The average length in subgroup A (23·83 mm.) is greater than in groups A and D but less than in group B. The difference between the average incisor lengths of group A and group B before treatment was statistically significant at the 2 per cent level.

Resorption

The average resorption in group A cases was 2·18 mm. at the end of treatment. At the end of retention average resorption was 2·08 mm., and at recall (at least 1 year after retention ceased) resorption was on average 2·73 mm. (these latter figures are anomalous in that some case records were incomplete). The maximum resorption recorded for each case averaged 2·5 mm. (the measurement being taken from the last available lateral skull radiograph in each case). There were 2 cases in group B with resorption of 1 mm. and 1·5 mm. respectively, which had not been previously noted. In group C there were 2 cases with 1 mm. resorption and 1 case with 2 mm. resorption. It should be noted that the

measurements of resorption have not been corrected for cephalostat magnification which is relatively unimportant with the small values involved.

The main differences between group A and subgroup A were the very high incidence of Class II, division 1 malocclusions and the 100 per cent occurrence of lip incompetence and overjet increase in subgroup A. There was also a greater incidence of relapse in subgroup A and resorption increase was greater on average during retention and on subsequent recall in these cases.

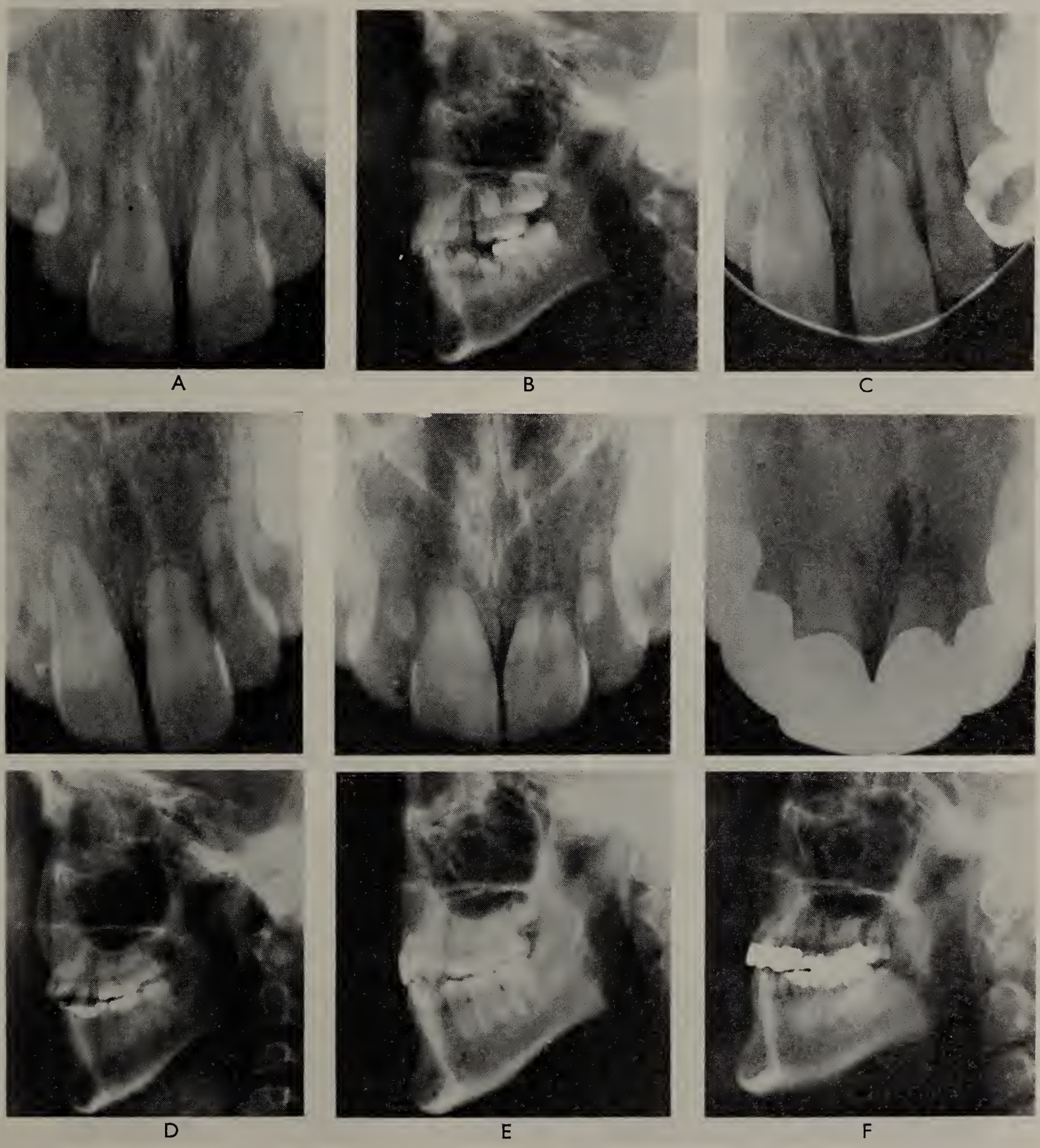


Fig. 8.—Radiographs of a patient who had severe progressive resorption following very limited orthodontic treatment. A, Intra-oral radiograph before treatment, aged 9 years. B, Lateral skull radiograph before treatment, aged 10 years. C, Before limited (2 months) treatment to $\underline{|1}$, aged 13 years. D, After limited (2 months) treatment to $\underline{|1}$, aged 13 years. *Above*, Intra-oral radiograph. *Below*, Lateral skull radiograph. E, Acrylic splint fitted, aged 16 years. *Above*, Intra-oral radiograph. *Below*, Lateral skull radiograph. F, After fitting permanent splint, aged 21 years. *Above*, Intra-oral radiograph. *Below*, Lateral skull radiograph.

CORRELATION OF POSSIBLE AETIOLOGICAL FACTORS

Sex

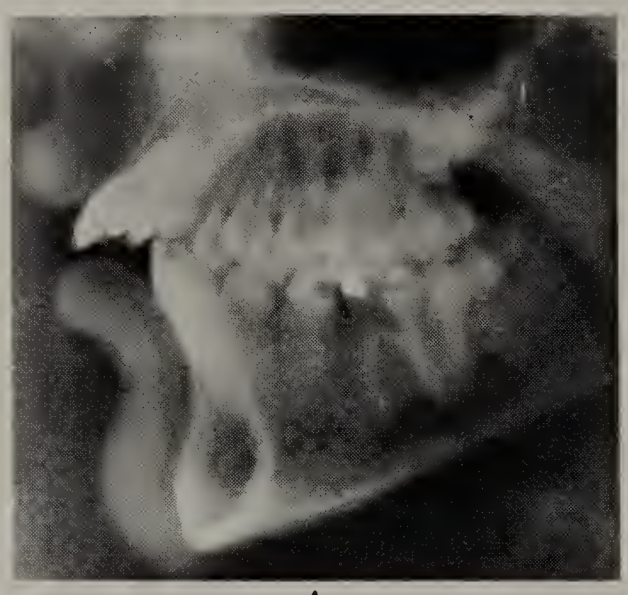
There was a greater number of females in group A (61·76 per cent) compared with group B (52 per cent). However, the average overall maximum amount of resorption in group A females was 2·55 mm. and in group A males 2·38 mm. (group A average 2·5 mm. resorption). This difference between the average maximum resorption occurring in females compared with males is *not* statistically significant.

Age at Commencement of Treatment

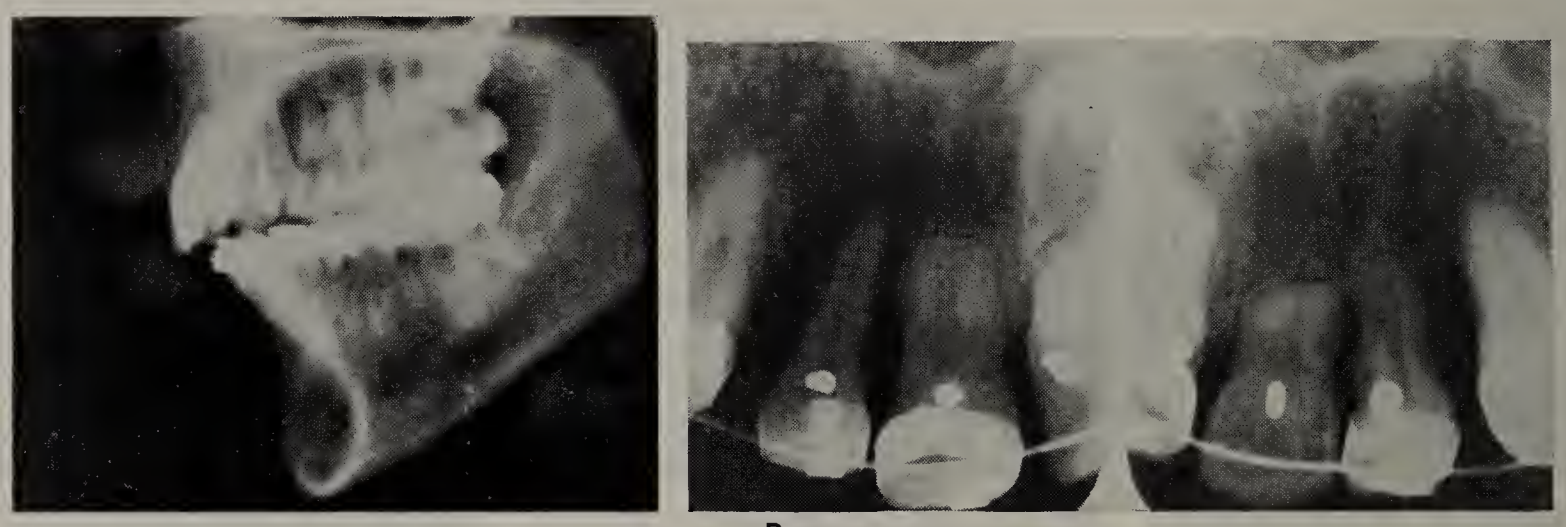
Since the average age at institution of treatment in group A (13·50 years) was greater than in group B (11·61 years) and this difference *was* statistically significant it was felt that resorption may occur with increased frequency with increased age. Since the age-group 11–12 years had the greatest average resorption (3·07 mm. for 7 cases!) there would seem to be no definite overall relationship between the *degree* of resorption and the age at the inception of treatment. It would seem, however, that there is an increased *incidence* of resorption in those patients who are older at the commencement of orthodontic treatment, although the amount of resorption was, in fact, greatest in those patients aged 11–12 years at commencement of treatment.

Length of Treatment

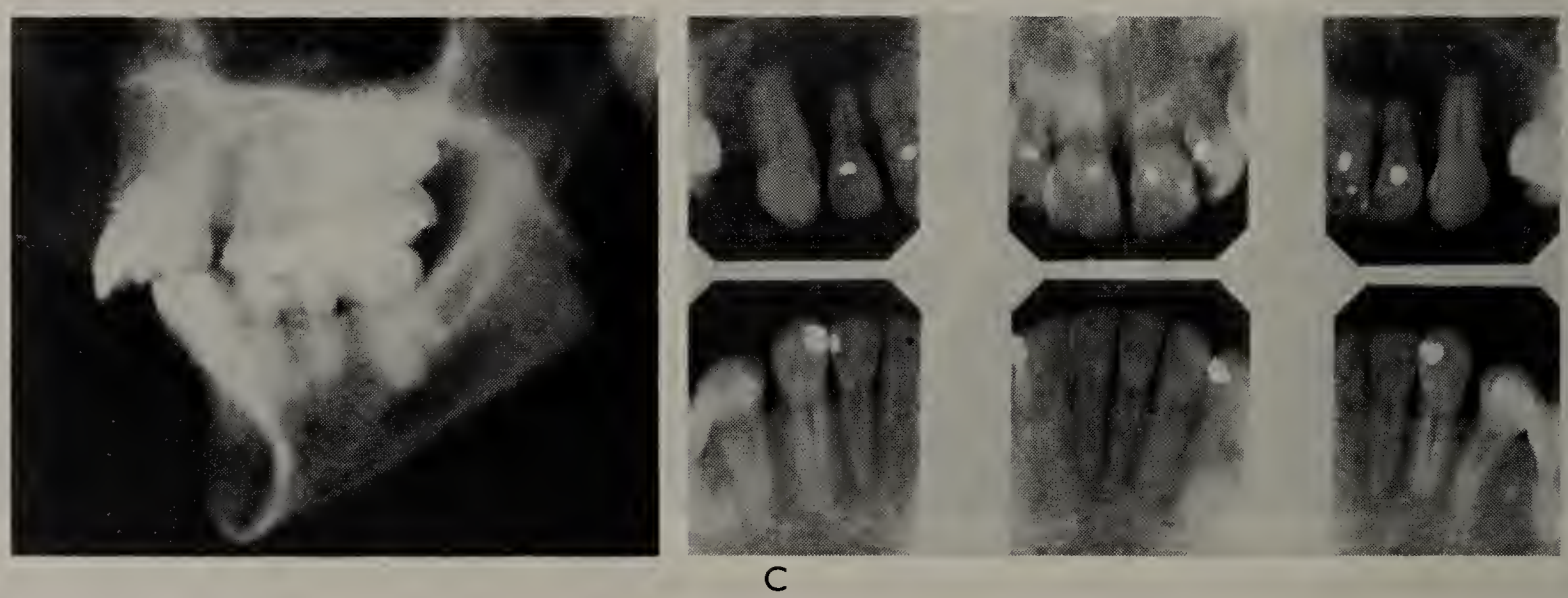
The average length of overall treatment and of treatment to $\underline{21|12}$ was greater in group A than in group B. However, 3 patients from group A had



A



B



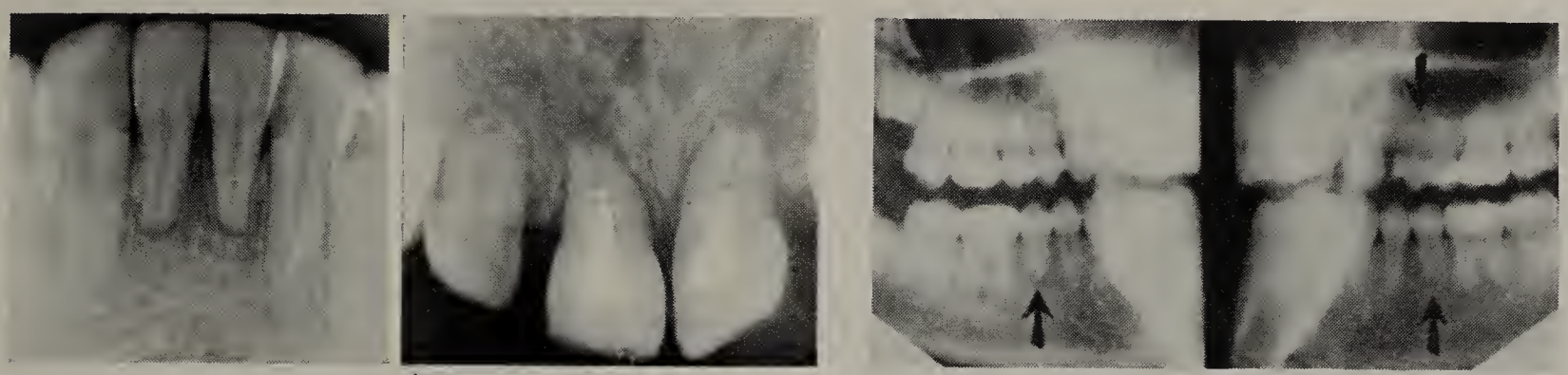
C

Fig. 9.—Radiographs of a patient with almost complete relapse of overjet following treatment. A, Before treatment. B, After treatment. *Left*, Lateral skull radiograph. Note the incomplete reduction of the overjet. *Right*, Intra-oral radiographs $\underline{21|12}$. Note the resorption of $\underline{321|123}$ (especially $\underline{1|1}$). C, Three years after the end of treatment, aged 20 years. *Left*, Lateral skull radiograph. Note the relapse of the overjet. *Right*, Intra-oral radiographs showing resorption of $\frac{21|12}{21|12}$ and also slight resorption of $\frac{3|3}{3|3}$.

treatment to 21|12 lasting over 2 years; in these 3 cases the average resorption was 2·17 mm. only. Interrelating the factors of age at the start of treatment and the length of treatment produced no values far from the mean resorption figure of the whole group.

Appliance Therapy

The incidence of fixed appliances and those appliances in which apical torque was utilized was statistically significantly greater in group A than group B.



A B C

Fig. 10.—Radiographs of a male aged 15 years showing widespread root resorption. No orthodontic treatment had been undergone. A, Intraoral radiographs of the anterior teeth. B, Half-plate radiographs. Note 'stunting' of the premolars (arrowed). C, Lateral skull radiographs.

Soft Tissues

The increased incidence of lip incompetence and anterior oral seals maintained by tongue to lower lip contact in cases with above-average resorption tends to confirm the commonly held view that 'jiggling' of the teeth is a factor in the aetiology of resorption of upper incisors. Functional appliances which may produce a similar 'jiggling' force on the upper incisor teeth were rarely involved in the treatment of cases in this survey. The total incidence of functional appliance therapy in all orthodontic treatment carried out in the institution from which this survey was made is low, however.

DISCUSSION

I would suggest that resorption cases may be divided into three categories:—

1. Those whose Incisors will resorb anyway

In the case illustrated in *Fig.* 8 little orthodontic treatment was carried out (13 months total). The only active treatment to the upper labial segment was 2 months with a fixed appliance to aline |1|. The upper incisors were relatively short at the start of treatment (21 mm.) and 2·5 mm. resorption occurred during the time of treatment. A permanent splint is now being worn because of upper incisor mobility, and 2·5 mm. further resorption had occurred by 21 years (8 years after treatment had finished). Resorption is, therefore, progressive. There is no evidence of generalized root resorption.

2. Those Cases in which Resorption occurs after the Start of Orthodontic Treatment in which Permanent Overjet Reduction does not occur

A permanent lip-to-lip anterior oral seal is not possible in these cases and therefore a tongue-to-lower-lip anterior oral seal persists. It is likely that the tongue-to-lower-lip seal prevents overjet reduction or, if overjet reduction is possible, causes relapse. Resorption occurs because a force contrary to the orthodontic appliance, i.e., the tongue, is always present. In the case shown (*Fig.* 9) the overjet was reduced from 11 mm. to 5 mm. but subsequently relapsed to 9 mm.

Lengthy treatment in these cases if overjet reduction is slow is very liable to produce resorption. It is therefore imperative when overjet reduction is slow that a fixed appliance is utilized in which the intramaxillary traction is operator activated. Poor patient co-operation is thus eliminated. If overjet reduction continues to be slow then orthodontic treatment should be

discontinued. It may well be this type of case which has given orthodontic treatment its ' bad name ' with regard to root resorption of the upper incisors. Root resorption tends to be of the magnitude of 2 mm.

3. Those Cases in which Slight Resorption (1–2 mm.) occurs probably as a Direct Result of the Appliances used

Slight resorption may occur from the use of appliances in which a torque force is applied to the upper incisors. It is probable that these slight



Fig. 11.—A patient with no orthodontic treatment. Note the slight ' shaving off ' of the anterior part of the apices of $\underline{1|1}$.

resorption cases occur more frequently than was found in this investigation. More widespread use of upper and lower multiband appliances tends to place emphasis on the length of the upper incisor roots especially when they are thrown forward initially and then torqued palatally as in the Begg technique. More frequent radiographic checks and measurement of incisor lengths will certainly bring more cases of resorption to light and also will make clinicians more aware of those cases in which resorption occurs. It should, however, be remembered that 3 cases with slight resorption were found in group C (20 non-orthodontic treatment controls).

In addition, certain individuals do have a predisposition for resorption no matter which appliances are used, or, in fact, resorption may occur in the absence of appliance therapy. In the case shown in *Fig.* 10, a boy aged 15 years, no orthodontic treatment was undertaken and there was apparent widespread root resorption. The stunting of premolar roots, as seen in *Fig.* 10, is thought to be an indication of a predisposition to root resorption (Ballard, 1970).

Local morphological factors may predispose individual teeth to root resorption, for example:—

a. Upper incisors roots may be ' shaved off ' on their labial surfaces as in the case shown in *Fig.* 11. This patient had had no orthodontic treatment.

b. It is possible that short-rooted teeth are more liable to root resorption, being less able to withstand strain. This tended to be borne out by the average incisor lengths of group A (22·89 mm.) compared with group B (24·26 mm.). However, subgroup A had an average root length of 23·83 mm., which was greater than group A.

c. If an individual tooth is placed in traumatic relationship considerable resorption may occur as already shown.

CONCLUSIONS

No single aetiological factor can be cited for resorption of upper incisors during orthodontic treatment.

The individual predisposition to root resorption in certain cases tends to modify all attempts to clarify aetiological factors. In this survey statistically significant findings were limited to the following factors:—

1. The age at the start of orthodontic treatment; group A greater than group B (5 per cent level of significance).

2. The incidence of Class II, division 1 malocclusions; subgroup A greater than group B. (5 per cent level of significance).

3. The overjet dimension before treatment; group A greater than group B (5 per cent level of significance).

4. Appliance therapy.

a. The incidence of fixed appliances only; group A greater than group B (5 per cent level).

b. The incidence of apical torquing force; group A greater than group B (5 per cent level).

5. The length of the upper central incisors before orthodontic treatment; group A less than group B (2 per cent level of significance).

In addition, there was a consistent trend in other features throughout the comparisons for the resorption cases to be orthodontically more difficult, viz., longer treatments, increased retention, increased relapse, and it is possible that further statistical significances would have been elicited if larger groups had been available.

SUMMARY

A series of 34 patients who had resorption of their upper incisors following orthodontic treatment (group A) were investigated and compared with an orthodontically treated control series

(group B) and also a non-orthodontically treated series (group C).

No single specific aetiological factor was found but a number of contributory factors are suggested together with an individual predisposing factor which is idiopathic and may be systemic (Ballard, 1970).

Acknowledgements

I wish to thank Professor C. F. Ballard, Mr. S. G. McCallin, Dr. J. R. E. Mills, and Mr. M. S. E. Gould for permission to publish details of their cases, and Professor Ballard and Dr. Mills for their help and constructive criticism. I am grateful to Mr. J. Morgan and Miss J. Wright for helping with the preparation of the slides and Miss J. Jeffrey for her excellent secretarial assistance.

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GINGIVITIS AND IMBRICATION

S. ALLDRITT, M.D.S.
The Queen's University of Belfast

IRREGULARITY in tooth alinement is often associated with long-standing inflammatory changes in the gum investing such teeth. It is generally accepted that gingivitis is a response to irritation by surface bacteria, so that the role of imbrication in the aetiology of gingivitis is one of predisposition, assuming of course that there is a causal relationship between the two conditions. Their association may well be fortuitous since gingivitis is not invariably found around imbricated teeth and imbrication is certainly not a necessary element in the development of gingivitis.

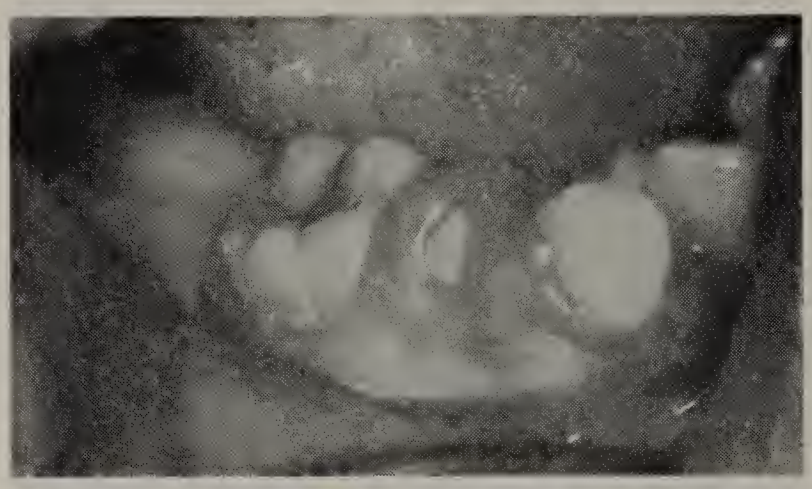


Fig. 1.—Girl aged 11 years showing almost total failure of gingival atrophy associated with erupting $\overline{5}|$.

The most obvious way in which malalinement may predispose to gingivitis is by rendering certain parts of the clinical crowns inaccessible to cleaning processes, but clinical experience indicates that there are other possible relationships between gingivitis and imbrication and it is with these that we shall be mainly concerned.

The subjects of orthodontics and periodontics share the same tissues—teeth, gum, bone, and periodontal ligament—and they are both concerned with the two systems which these tissues constitute. In one of these systems, the ' dento-periodontal ' system, the individual tooth is seen in relation to the other teeth and to its gum, bone, and ligament. In the other system, the ' gingivo-skeletal ' system, the gum is seen in relation to the teeth and bone. The skeletal part of this

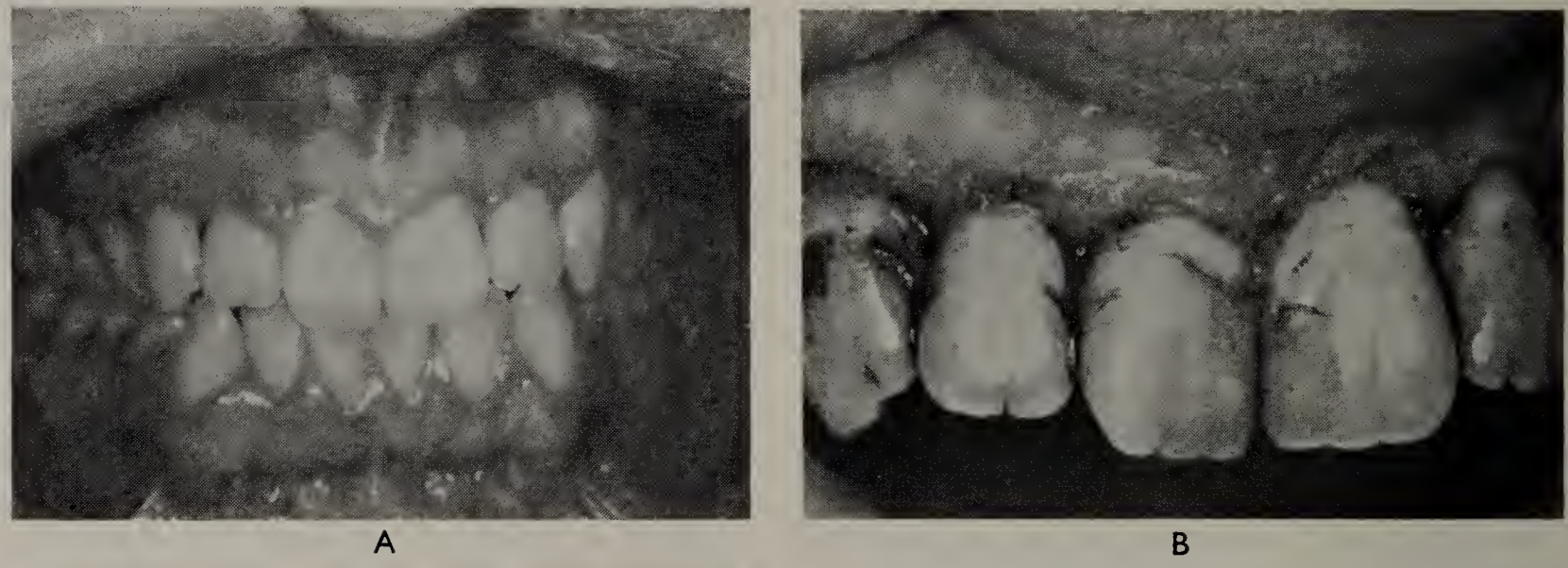


Fig. 2.—Female aged 17 years. A, Excessive gingival investment of the maxillary incisors. B, Appearance of the teeth following electro-surgical excision of the excess gum. The former level of the gingival margin is discernible and indicates the depth of sulcus. C, The subgingival plaque disclosed.

Presented at the meeting held on 14 December, 1970.

gingivo-skeletal system comprises both the clinical crowns and those parts of the crowns, roots, and alveolar bone to which gum is directly related. The justification for defining such a system lies in the distinct functional roles of gum. An understanding of these functions not only provides the proper basis for studying gingival structure and form but also underlies the principles of gingival management.

Gum has a duality of functions in that it acts both as a mucous membrane and as a periosteum. When a tooth is fully erupted the proper functioning of gum depends very much upon the relation of the gingival margin to the enamel margin. The optimum level of gingival margin is one in which the margin lies on the crown as close to the enamel margin as the inherent characteristics of the epithelial attachment will allow. This is the optimum level for gingival function as a mucous membrane. This level of gingival margin can change as a result of inflammatory or hyperplastic pathology but it is also possible for variations in gingival level to occur which are developmental in nature. These may well predispose the gum to pathological changes, but for the moment identification of these variations is sufficient.

One of the developmental variations arises during the process of eruption. Instead of the gingival margin retreating to its optimum level on the crown the process becomes arrested at a more occlusal level.

Total failure of gingival atrophy during eruption seems to be rare (*Fig.* 1), but lesser degrees



Fig. 3.—Male aged 25 years with severe recession around the mandibular incisors but not involving the gingivomucosal junction. Note the symmetry and uniformity.

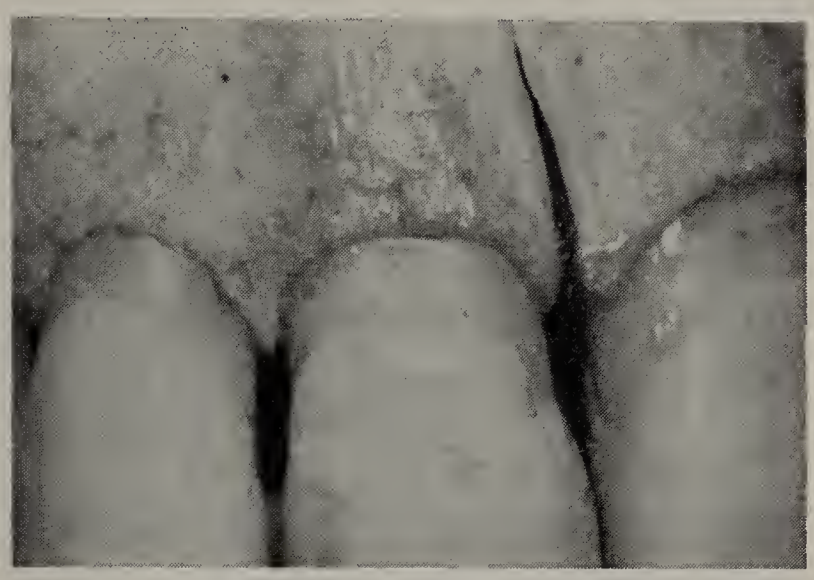


Fig. 4.—Dried specimen showing normal socket margin to enamel margin relation of $\underline{21}|$.

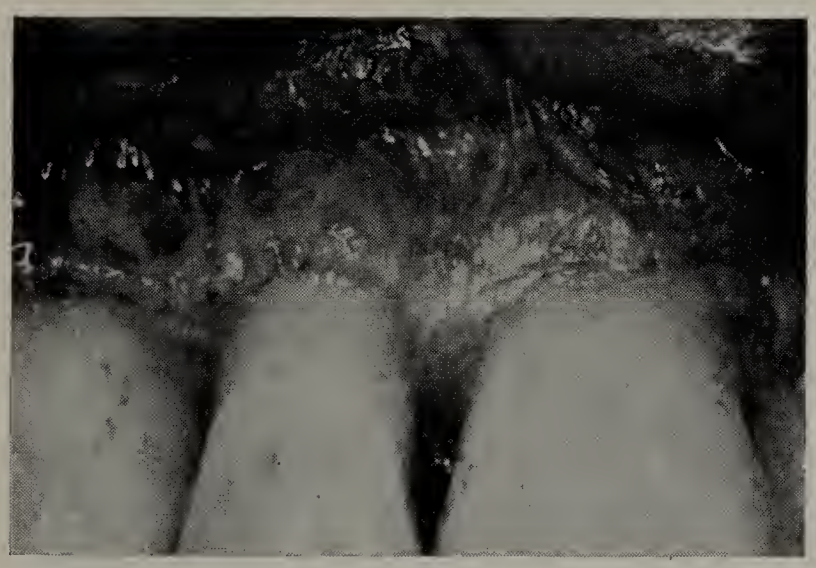


Fig. 5.—Normal socket margin to enamel margin relation of $\underline{2}|$.

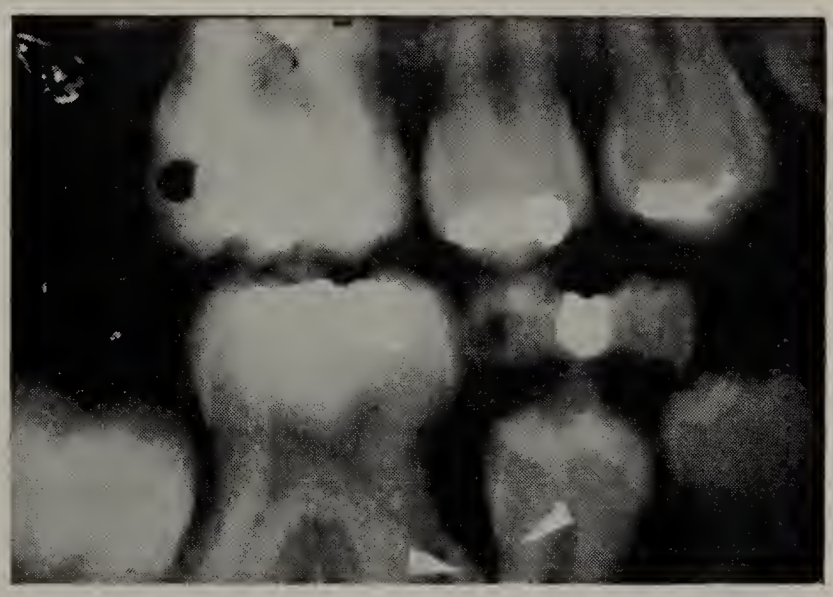


Fig. 6.—Boy aged 11 years. Radiograph showing crypt to enamel margin relation of $\overline{5}|$.

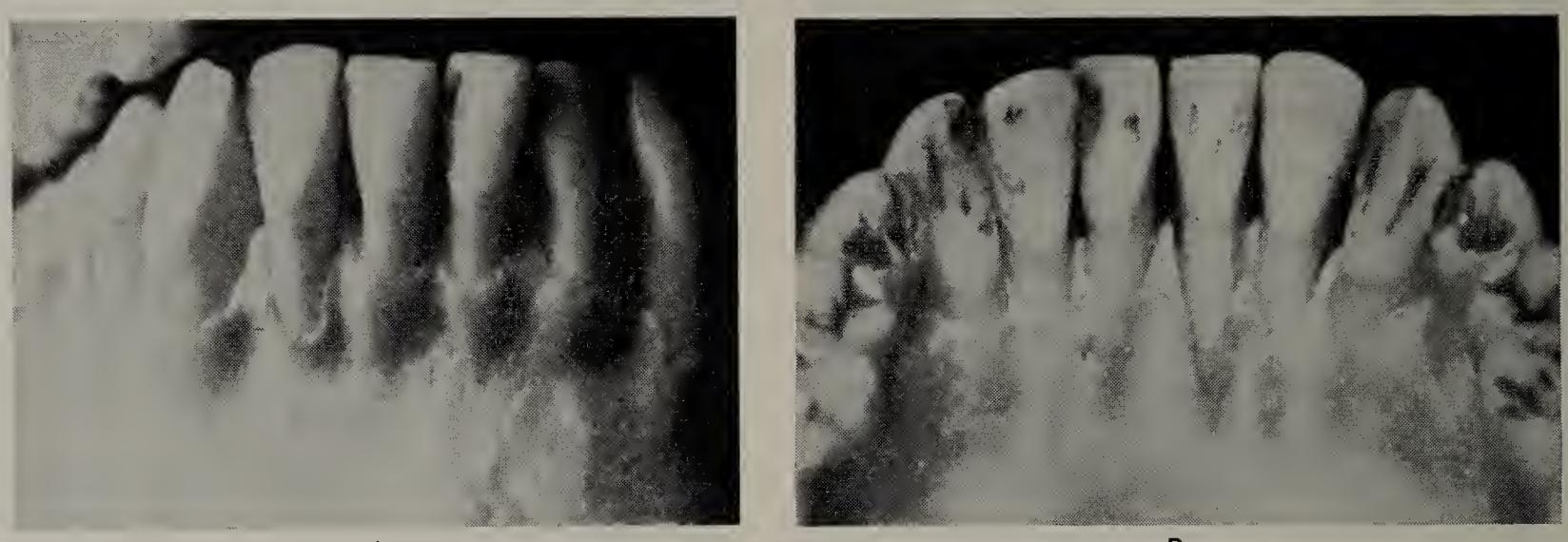


Fig. 7.—Same case as in *Fig.* 2. Note the relation of socket margin to enamel margin of $\underline{2}|$.

are common and result in a correspondingly excessive investment of the crown. The excessive investment may be a matter of only a few millimetres but any excess of gum predisposes to the formation of a gingival sulcus. A sulcus tends to reduce the competence of gum to act as a mucous membrane in so far as it permits the growth of subgingival plaque (*Fig.* 2).

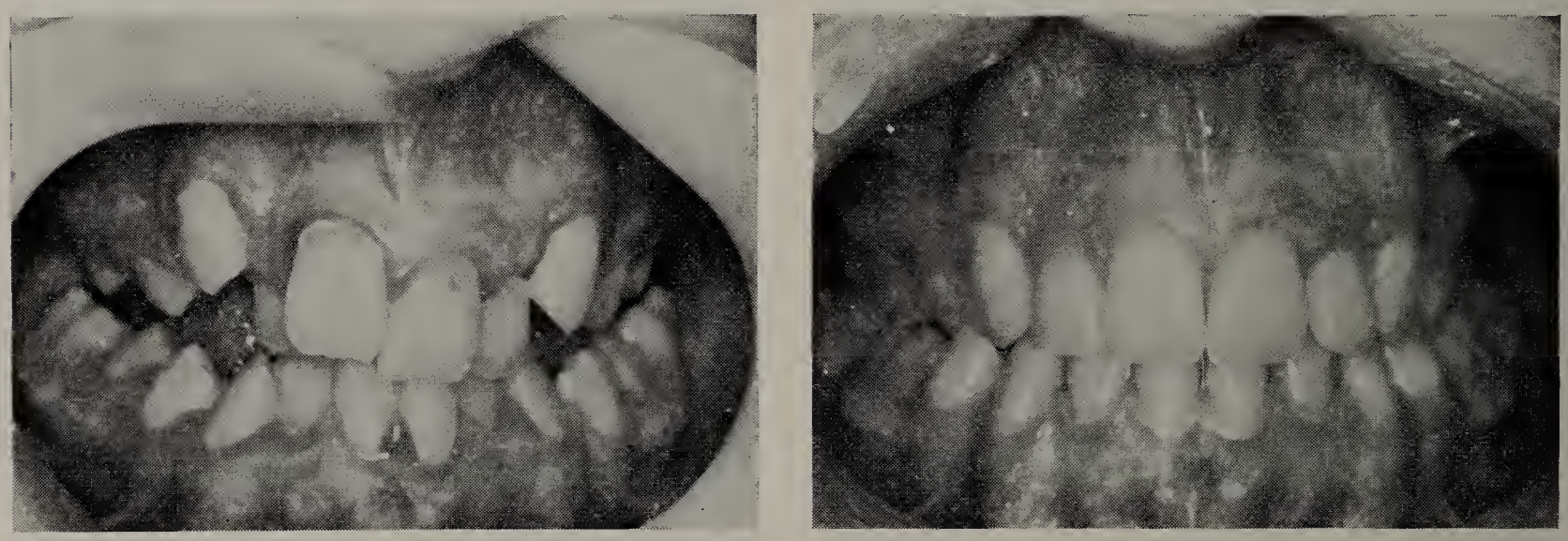
The aetiology of incomplete gingival development probably differs from case to case. It may be associated with certain types of skeletal variation, but it is also possible for it to be a definitive fault in the gum, in that it is not associated with an obvious abnormality in the tooth/bone skeleton.

The other variation in gingival level is a recession of the margin on to the root surface. There are various reasons why a gingival margin may recede but in the majority of cases recession occurs in gum which is otherwise healthy and for which there is no obvious explanation. It is common to dismiss the phenomenon as an age change without attempting to explain its selectivity, its frequent symmetry, and its spontaneous arrest. The fact that recession occurs in adult life masks its essentially developmental nature, in that it is secondary to a fault in the underlying bone (*Fig.* 3). Recession does not in itself reduce the ability of gum to act as a mucous membrane.



A B

Fig. 8.—A, Dried specimen, showing developmental bone deficiency affecting the labial aspect of the mandibular incisors. B, The lingual aspect of the mandibular incisors. Note the particularly severe underinvestment of $\overline{2}|$.



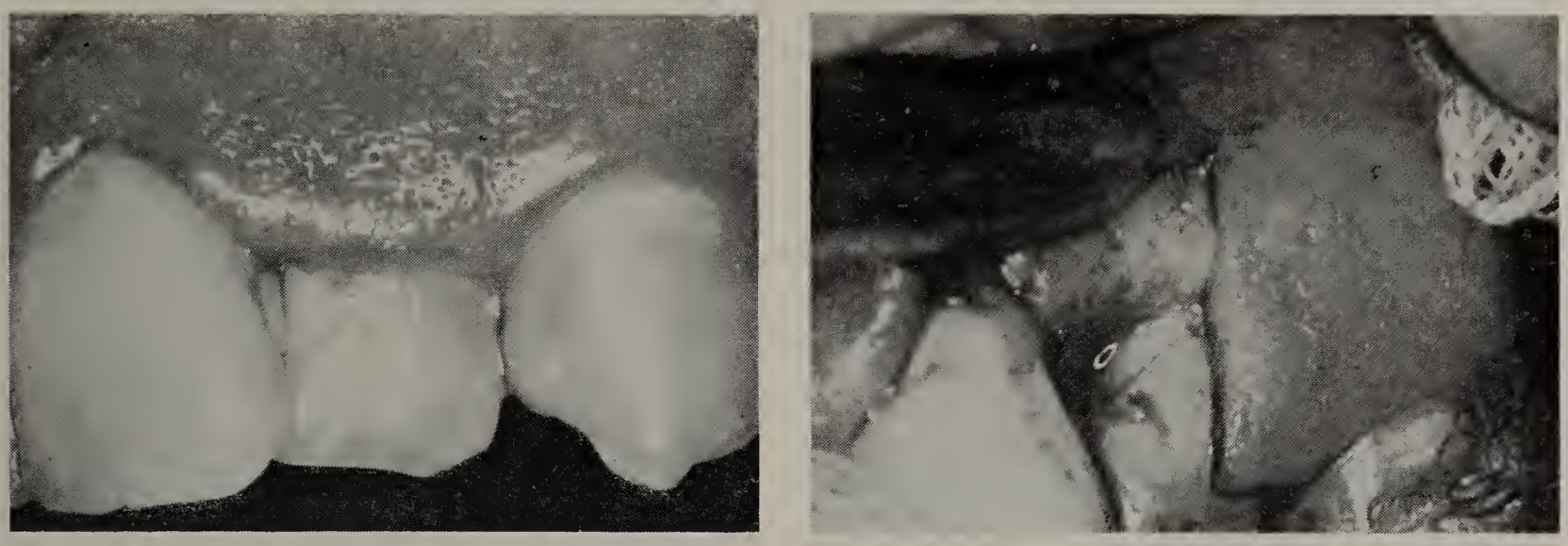
A B

Fig. 9.—Female aged 13 years. A, Gingivitis owing to heavy plaque formation. B, Appearance 2 years later following orthodontic treatment and impeccable home care.

Normal epithelial continuity between gum and tooth may be maintained so long as the receded margin does not encroach upon the gingivomucosal junction. However, recession does mean that the protective function of gum is lost with respect to the exposed root surface. In contrast to excessive investment of the crown which may occur on a normal skeleton, the process of recession must be seen in relation to the bone on which gum normally depends for its support.

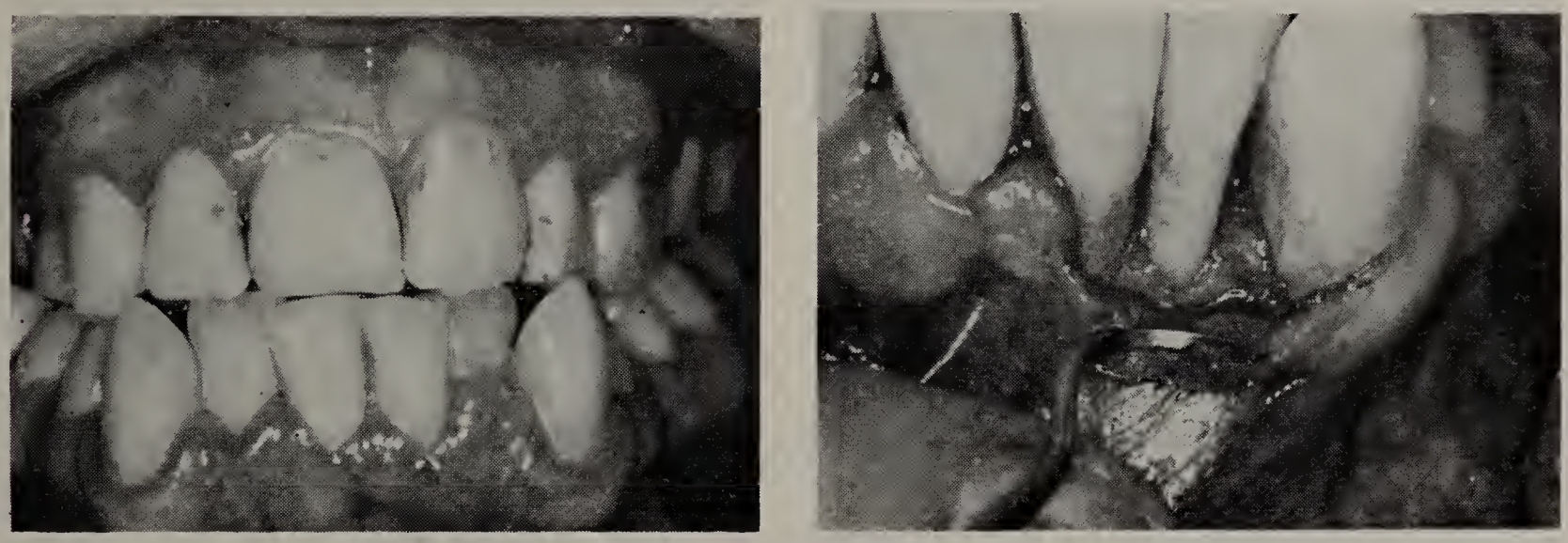
The skeletal aspect of recession will be mentioned again, but at this stage an attempt to define the optimum form of the skeleton in the gingivoskeletal system would be useful. The factors contributing to this are: (1) the form of the teeth, (2) the alinement of the teeth, (3) the form of the socket margin, and (4) the level of the socket margin on the root, or more precisely the relation

of socket margin to enamel margin. All these factors may exhibit variation so that the overall variation in tooth/bone form is extensive. The first of these factors, tooth form, is genetically predetermined and alterable only by extensive and rather uncertain crowning procedures. The second underlies orthodontics, whilst the third and fourth are the province of the periodontist. This is not to say that the orthodontist can afford to ignore bone level nor that the periodontist



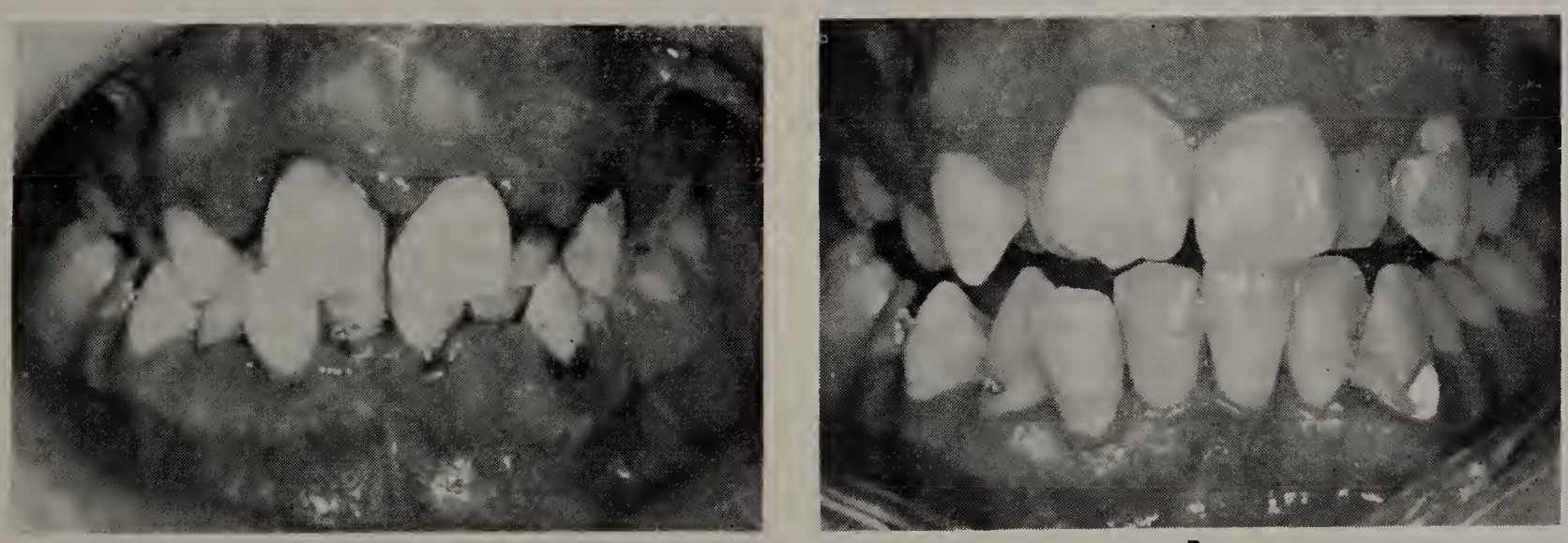
A B

Fig. 10.—Female aged 30 years. A, Instanding $|\underline{2}$ with excessive gum. B, Gum incised vertically with the mesial flap retracted. Note the extent of the gum investment of the crown, the socket level relative to the enamel margin, and the contour of the bone surface.



A B

Fig. 11.—Male aged 23 years. A, Marked inflammatory change in the gum overlying the instanding $|\overline{2}$. B, Deficiency of the bone investment of $|\overline{2}$.



A B

Fig. 12.—Female aged 20 years. A, Gingivitis superimposed on gingival excess. B, Appearance 2 months after gingivoplasty.

can ignore malalinement, but technologically the division is valid.

The optimum relation of socket margin to crown appears to be one in which the socket margin lies about 2 mm. from the enamel and is streamlined to the root contour. This idea is based partly on the features seen in dried specimens, partly on the features seen at operation, and partly on the results of surgical alteration of bone level. This is considered to be the optimum relation of socket margin to enamel since under these conditions the gingival margin may develop its optimum relation to the enamel margin and then maintain this level throughout life (*Figs.* 4, 5).

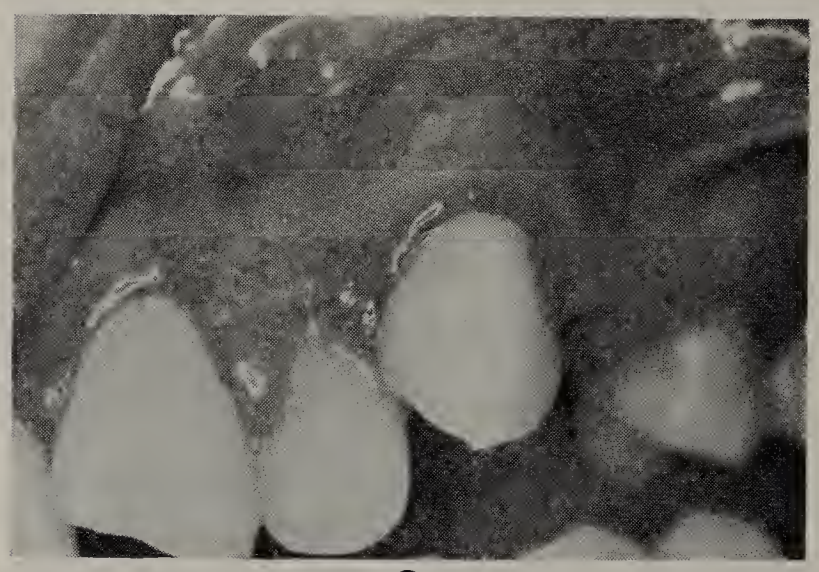
The relation of socket margin to enamel is an important factor in determining the configuration of the interdental space. The interdental space is a unique type of foramen in the body skeleton in that continuity of body surface must be maintained in the space. For this to occur tooth form, tooth alinement, bone form, and bone level must harmonize to permit the establishment of epithelial continuity between the teeth and the gum occluding the space. For such epithelial continuity to be functionally competent so that a gingival sulcus is not created there must be a precise correlation between the various tissues in their development and growth.



A



B



C

Fig. 13.—Girl aged 13 years. A, Marked excess of gum on the maxillary incisors. Note the normality of the gum on the mandibular incisors. B, Appearance 2 months following gingivoplasty. C, Appearance 8 months after gingivoplasty showing recurrence of papillary gingivitis on $\underline{|2}$.

The factors influencing the relation of socket margin to enamel margin are not clearly understood but the symmetry of these two landmarks can be very striking, suggesting that the relation may be established early on in development. A feature which supports this idea is seen in the radiological picture of developing teeth and their crypts (*Fig.* 6). The outline of the crypt at the enamel margin suggests that the follicle gains an attachment to the cervical cement, and if such an attachment were to persist throughout eruption it could conceivably influence the eventual level of the socket margin on the root. However, there are other factors which influence socket level since it is commonly found at operation that the socket margin does not lie at what is considered to be the optimum level on the root. In some patients the socket margin lies closer than 2 mm. and may virtually be in contact with the enamel (*Fig.* 7). When this variation occurs between the interdental crest and proximal enamel margins the interdental space is reduced in size, and should the crest extend to the contact area the interdental space may be patent to only the finest probe. Excessive investment of the root by bone is associated with some degree of excessive investment of the crown by gum. This is presumed to be due partly to the convex form of the enamel/bone surface which contrasts sharply with the depression presented by the normal cemental surface, and partly to the stimulation of the periosteal component of gum by the excessive bone. As has already been mentioned excessive gingival investment may present as a definitive anomaly on an otherwise normal tooth/bone skeleton. The fact that excessive bone investment causes some degree of excessive gingival investment of the crown is a complicating factor in the

clinical evaluation of gingival over-investment (*Figs.* 2A, 7).

The other type of variation in socket level presents as a greater than normal distance between socket margin and enamel. The severity and pattern of this anomaly is widely variable, we may say that when there is excessive gingival investment of the crown the underlying bone investment may also be excessive, but it is possible for it to be normal or even deficient. When the gingival margin is at its normal level on the crown the bone level may be at its normal level

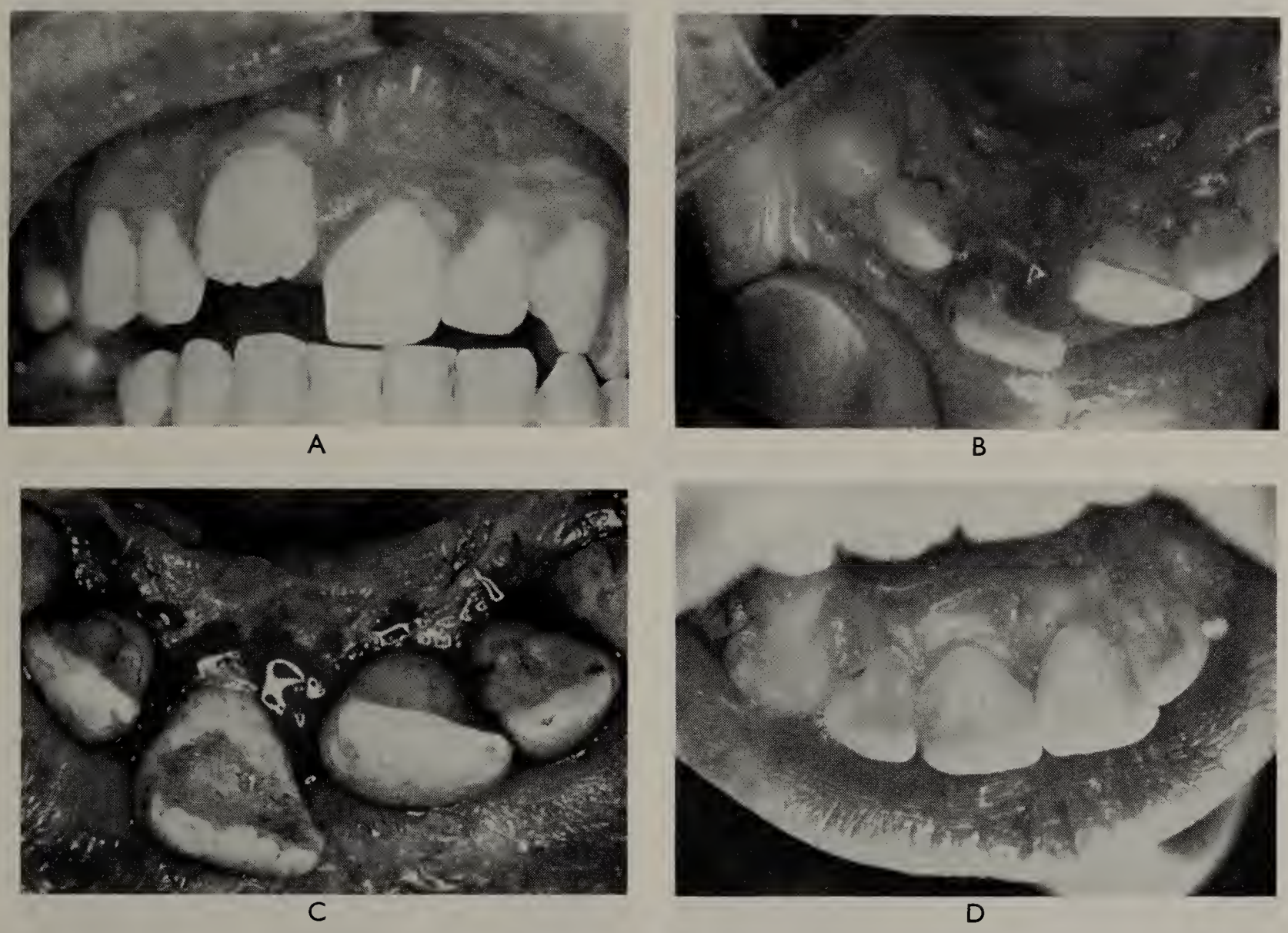


Fig. 14.—Boy aged 15 years. A and B, Labial and palatal views showing excess of gum impeding the alinement of $\underline{1}|$. C, Gingival excision palatally and interdentally. D, Appearance 10 months later.

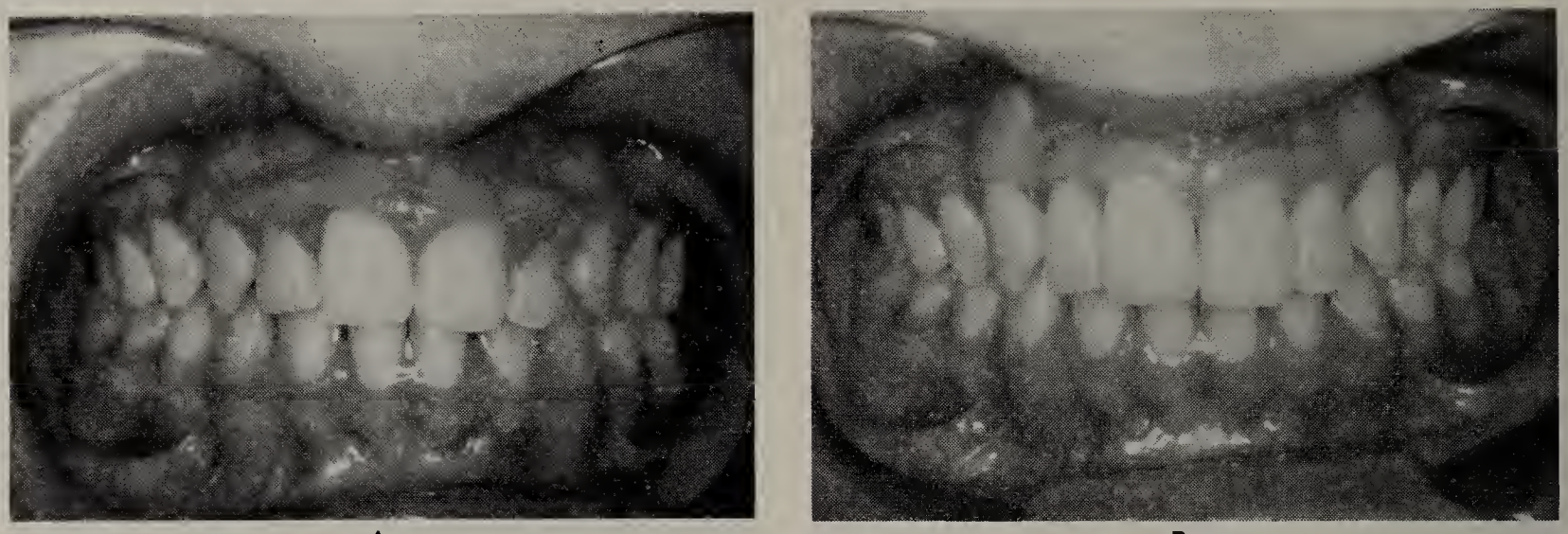
but it frequently affects corresponding teeth in the arches and in some cases to a similar degree. Deficiency of bone investment may be quite uniform throughout an arch, or it may affect only one aspect of the teeth. When it affects both inner and outer aspects of a group of teeth the level of the interdental crests tends also to be reduced, but not necessarily to the same degree as that exhibited by the socket margins overlying the roots (*Fig.* 8).

The importance of alveolar under-investment in the present context lies in the predisposition of the gum investing such a skeleton to undergo recession. In other cases under-investment may call attention to itself because of the diffuseness of gingivitis, or the presence of pocketing overlying the teeth.

So far the optimum levels of gingival margin and socket margin relative to the enamel margin, and also the anatomical variations which they may present have been considered. In summary, although there may be a deficiency of bone investment. In the case of recession, bone level is bound to be deficient, and when the process of recession is complete (always assuming that the gingivomucosal junction is not involved) the gingival margin is found to have taken up a relation to the socket margin similar to that seen between normal gingival margin and normal bone margin.

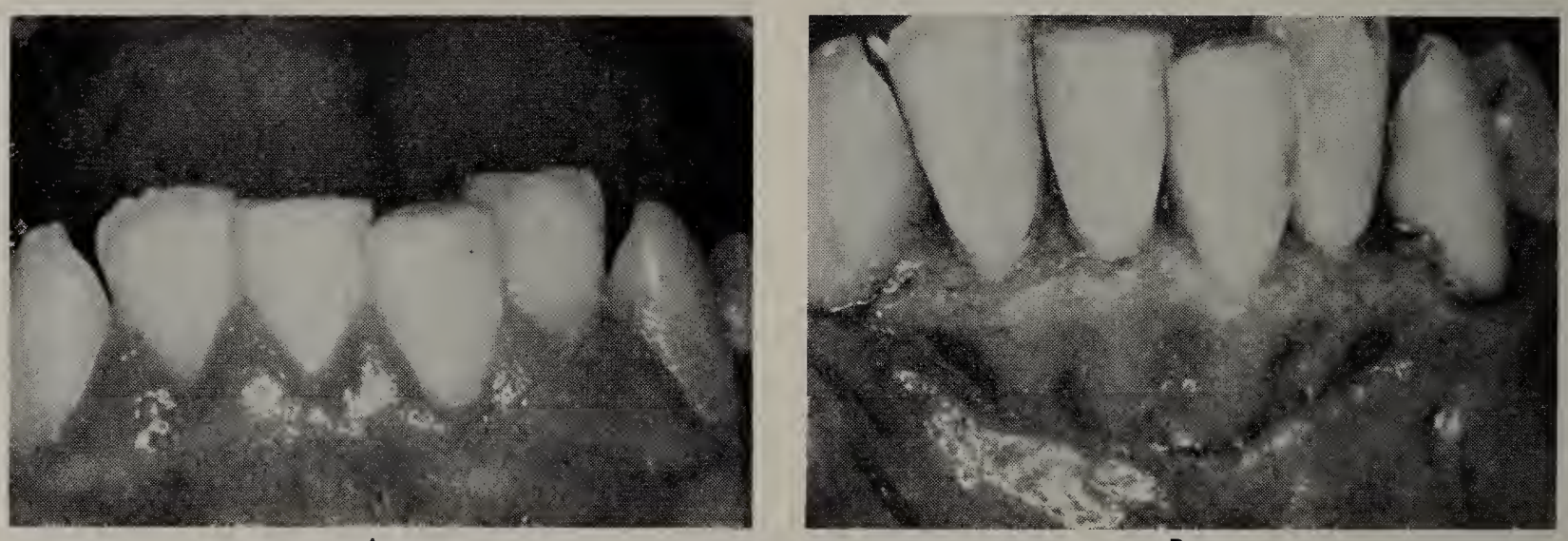
This brief review of certain aspects of gum/bone relation provides a background for consideration of the variations in the tooth part of the skeleton. These variations may occur in either tooth form or tooth alinement. The variation in tooth form which is of periodontal importance presents as a lack of pronounced proximal contour. This causes reduction in the size of the interdental space, and when the bone level is normal the interdental gum tends to be deeply cleft around the contact area and to suffer food impaction through lack of protection from the embrasures.

The problem of undercontoured crowns is masked when there is an excess of gum, and whether or not they contribute to the disordered gingival development they can certainly complicate post-operative care by the patient.



A B

Fig. 15.—Girl aged 15 years. A, Marked gingival deformity around the maxillary incisors following orthodontic treatment. B, Appearance 1 year after gingival surgery.



A B

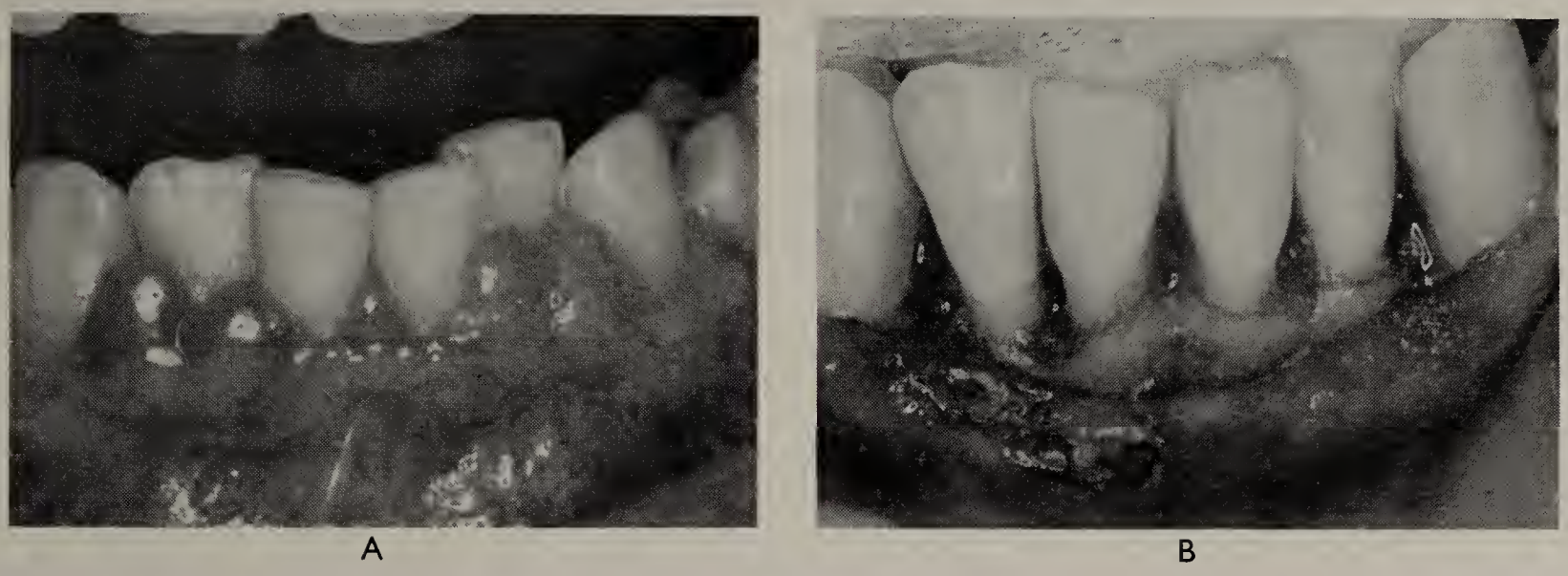
Fig. 16.—Girl aged 19 years. A, Gingivitis superimposed on excess gum associated with imbrication. B, Excessive bone investment.

This now leaves the factor of imbrication to be fitted into the picture of gum/tooth/bone variation. As noted earlier normal gingival development can take place around malalined teeth. Should gingivitis subsequently develop the response to plaque removal and proper home care will be similar to that which occurs in cases of normal alinement. With correction of the malalinement the gum undergoes spontaneous modification in form to the improved skeleton (*Fig.* 9).

The frequency with which malalinement and gingival over-investment are associated suggests that malalinement may have an adverse effect on the process of gingival development. The instanding crown with excessive gum on its vestibular surface is a common expression of this effect. In *Figs.* 10 and 11, 2 such cases are shown, with the bone investment in one case being excessive on the instanding tooth and in the other being deficient. Inflammation almost inevitably becomes superimposed on excess gum and enlarges the gum still further. In these cases the response to plaque removal and home care is usually disappointing, and at best incomplete, so that the only certain way of eliminating the excess tissue is by excision (*Fig.* 12).

The timing of gingival surgery might be mentioned here. Treatment should not be postponed in the hope that gingival form will undergo spontaneous improvement with age. As has been said this may occur with reduction in the malalinement when the gum/bone form is essentially normal, but is limited when there is an excess of gum. The advantage of carrying out gingivoplasty before orthodontic treatment is that the optimum conditions are created for the development of functional gingival form as the orthodontic treatment proceeds. Furthermore, the possible impediment to tooth movement which excessive tissue may offer is eliminated and there is, of course, the point that the size of the clinical crowns is increased, thus rendering them readily

accessible to the orthodontist. When possible, gingivoplasty should be carried out just before the start of the orthodontic treatment. It is difficult for children to maintain the necessary standard of cleanliness around crowded teeth,



A B

Fig. 17.—Girl aged 13 years. A, Marked inflammatory change around the mandibular incisors. B, Flap retracted to reveal active resorption of the interdental septa and socket margins.

and if there is an undue interval between surgery and the start of orthodontic treatment relapse is more than likely (*Fig.* 13).

A need for gingivoplasty may arise during the course of orthodontic treatment as a result of extensive alteration in the relation of one tooth to another, or in the inclination of the teeth such as may occur when proclined teeth are retracted. The excessive gingival tissue may make the completion of alinement difficult, in which case the gum should be excised fairly severely (*Fig.* 14). Orthodontic movement should be restarted as soon as the gingival wound may be left undressed.

Pre-orthodontic gingival surgery and surgery during orthodontic movement have been mentioned. This leaves the important matter of gingival evaluation once orthodontic treatment is complete. Whether gingival surgery has already been carried out or not careful examination of the gum should be an integral part of post-orthodontic examination. It must be remembered that tooth/gum relation may be normal before orthodontic treatment and abnormal afterwards so that the orthodontic treatment predisposes the gum to inflammation (*Fig.* 15).

So far, the type of case in which imbrication is associated with gum which is either healthy or essentially normal in its tooth/bone relation, despite inflammation, and the type of case in which imbrication is associated with a developmental excess of gum have been discussed. The type of case in which imbrication is associated with excessive gum and excessive bone investment has not yet been mentioned (*Fig.* 16). When treating such a case in an adult, excision of the excess gum is followed by the preparation of a gingival flap and osteoplasty to reduce the bone level and thickness. In a child the gingival excision should be carried out, but precise osteoplasty is difficult on account of the fibrous content of the bone at this stage. One is therefore inclined to avoid osteoplasty in a child in favour of long-term observation of the case. Correction of the malalinement is highly desirable, but our experience of this type of case is limited so that it is not yet possible to say what effect correction of the malalinement has on bone form. One important point that should be mentioned with regard to these cases is that the excessively high level of bone may well predispose to its inflammatory involvement at an early age (*Fig.* 17). This is another indication, if any were needed, that gingivitis in the child is a serious matter and deserves much more attention than it has received in the past.

SUMMARY

Gingivitis and imbrication may occur in fortuitous association but a causal relation between the two is possible. At the present time it is recognized that certain types of anatomical variation may occur in the gum and in the bone, and to these must be added the variations in the form and alinement of the teeth in order to encompass the whole spectrum of variation in the gingivo-skeletal system. There seems little doubt that imbrication can adversely affect gingival development and that bone level can influence gingival level, but the relation between imbrication and bone level is not understood.

Orthodontic treatment is capable of improving interspace configuration with respect to its dental components, and possibly also with respect to bone height, but this aspect needs to be investigated. Orthodontic treatment increases the effectiveness of the self-cleansing mechanisms of the mouth and renders the teeth more accessible

to the toothbrush. Gingival surgery corrects deformity and eliminates the gingival sulcus. It allows inspection of the socket margins and eliminates inflamed tissue.

The co-ordination of orthodontic and gingival treatment requires careful planning and much effort by everyone concerned, but the results can be extremely gratifying. In some cases the indication is for gingival surgery first followed by the orthodontic treatment, whilst in others the orthodontic treatment comes first and is followed by a critical examination of the gum, with surgical correction of residual deformity being indicated as soon as possible.

Acknowledgements

The Author is indebted to Mr. C. P. Adams, Mr. A. Richardson, and his other orthodontic colleagues for their co-operation in the combined treatment of the cases shown, and to Mr. W. Hurt, Chief Photographer of the Royal Victoria Hospital, Belfast, for the photographic work.

ORTHODONTIC AND SURGICAL OBSERVATIONS ON THE REMOVAL OF MANDIBULAR THIRD MOLARS BY LATERAL TREPANATION

P. T. BURGESS, B.D.S., F.A.C.D.S., D.Orth.

W. J. B. HOUSTON, B.D.S., F.D.S., D.Orth.

G. L. HOWE, T.D., M.D.S. (Dunelm.), M.R.C.S. (Eng.), L.R.C.P. (Lond.), F.D.S. R.C.S. (Eng.), F.F.D. R.C.S. (Ire.)

Royal Dental Hospital, School of Dental Surgery, London

Lower third molars are commonly impacted and may present surgical, periodontal, and orthodontic problems. While serious surgical complications of third molar removal and impaction are less common that they were (Bowdler Henry, 1938) before the introduction of antibiotics, they still do occur and have been reviewed by Kay (1966).

The periodontal sequelae of third molar impaction have attracted less attention. Ash, Costich, and Hayward (1962) found pockets distal to second molars before surgery in nearly 30 per cent of patients with impacted third molars, and in over 50 per cent of the same cases 1 year after surgery. These authors concluded: ' All impacted or potentially impacted third molars should be extracted as early in their development as possible to prevent the high incidence of loss of supporting structure on the distal of second molars.' Although Groves and Moore (1970) suggested that removal of impacted lower third molars might prevent further deterioration in the periodontal condition of the lower second molar, they reported bone loss distal to second molars in over 20 per cent of their cases after surgery.

The effects of third molar impaction on the occlusion are not clear. A belief commonly held is that such teeth may promote mesial drift of buccal segments and so contribute to late incisor crowding. Bergstrøm and Jensen (1960) found, in a group of young adults with unilateral absence of one lower third molar, that there was slightly greater crowding on the side where the third molar was present. However, there is little reliable information on this subject and third molars are certainly not the only factor involved in late incisor crowding. Nevertheless, it is a matter of debate whether the orthodontist can regard a patient as having completed treatment before third molars have either erupted into occlusion or have been removed. In consideration of the possible orthodontic complications some attention has been directed to the circumvention of third molar impaction. Bjørk, Jensen, and Palling (1956) point out that where teeth are lost further forward in the arch, the prevalence of impaction is reduced. Extraction of premolars has been claimed to reduce third molar impaction (e.g., Faubion, 1968). Lower second molars are often extracted either as part of an overall orthodontic treatment plan or with the sole aim of providing space for the third molars. Smith (1958) reported that only 17 out of 34 patients who had lower second molars extracted for orthodontic reasons had third molars ' with an acceptable axial inclination on eruption '. Cryer (1967) found the most favourable results where second molars were extracted at the time of completion of third molar crowns. At this stage 70 per cent of third molars erupted into a good position although when second molars were removed at other stages good results fell to less than fifty per cent. He comments: ' variability seems the most apt description of third molar behaviour '.

Another approach to prevention of impaction is early removal of the third molar itself. Bowdler Henry (1934, 1938) described his operation for enucleation of the third molars at an early stage when they are still superficial, preferably before the union of the cusps. Although this is an ingenious approach, many orthodontists and dental surgeons have had reservations about committing a patient to the loss of the third molars during the

early mixed dentition stage when there is still an appreciable amount of growth to occur and when there is the very real risk of the loss of other teeth, either due to caries or for orthodontic reasons. Some 35 years later Bowdler Henry (1969) described a method of removing the lower third molars via a buccal approach at a later stage when the crown is completed. At this stage there is a much better chance of correctly assessing the potential impaction, and the caries and orthodontic status of the patient is much more clearly defined. This operation is undertaken earlier than the conventional surgical approach and before the third molar can have had any deleterious effects on either the periodontal condition of the second molar or on crowding in the lower arch.

Bowdler Henry published a description of this ingenious and original technique, which he called ' lateral trepanation ', in 1969. One year earlier he was kind enough to send one of us (G.L.H.) full details of the operation which he had devised and the research on which it was based. This generous action has made it possible to complete the study which forms the subject of this paper much earlier than would otherwise have been the case, and we are indebted to him.

CASE SELECTION

Patients were selected for inclusion in this clinical study only when it was considered that there was little or no chance of their lower third molars erupting into a normal position. The crowns of these teeth were at least one-half calcified and root formation was no more than one-third completed. The choice in treatment was either the early removal of the third molar by lateral trepanation, or the extraction of the lower second molar to relieve the impaction of the third molar, or postponing surgical intervention in the knowledge that removal of an impacted third molar by a conventional surgical technique would probably be required at a later stage.

The assessment of the degree of third molar impaction was made on subjective grounds, based upon the position of the tooth and an estimate of the space available to accommodate it. The prognosis for eruption into a good position was considered to be unfavourable when the occlusal surface of the third molar was inclined at an angle of more than 30 degrees to the long axis of the second molar, or when the space available between the distal margin of the second molar and the ascending ramus of the mandible was less than one-half the crown width of the third molar.

In most cases no active orthodontic treatment whatsoever was undertaken in the lower arch but in several cases orthodontic treatment involving the extraction of other teeth had been performed at an earlier stage. The removal of the third molars was performed with the object of eliminating the impaction rather than either preventing or relieving incisor crowding.

SURGICAL PROCEDURE

The procedure which Bowdler Henry (1969) described is a delicate and dainty technique in which a small incision in the sulcus is used to expose the buccal plate in the mandibular third molar region. The follicle of this tooth is then trephined with a spear-point drill and is exposed by the removal of an ovoid portion of buccal plate, leaving the external oblique ridge intact. The tooth is ' tickled out ' with a Warwick James elevator.

Although a number of problems were encountered when this technique was employed by us, all operations were completed successfully and the end results were sufficiently impressive to convince us of the value of the approach. A series of minor modifications were made in an attempt either to avoid or to overcome the difficulties which had been experienced, and all the patients included in this paper were operated upon using the technique illustrated in *Fig.* 1. The patients were treated under endotracheal anaesthesia on a day-bed basis except when either the need for further surgery elsewhere in the mouth or social reasons made it necessary to admit them.

TECHNIQUE EMPLOYED

After palpating the external oblique ridge an extended S-shaped incision is made from the retromolar fossa, across the external oblique ridge, curving down through the attached mucoperiosteum to run along the reflection of the mucous membrane to the anterior border of the first permanent molar (*Fig.* 1A). Experience has revealed the importance of leaving a cuff of attached mucoperiosteum, 5 mm. in width, distobuccally to the second molar.

The soft tissues lying behind and below the incision are readily elevated from the surface of the bone and held away with a Bowdler Henry retractor (*Fig.* 1B). A round Toller bone bur in a straight handpiece is used to trephine the position of the crypt of the third molar which always appears to lie further forwards than one would imagine. When the anteroposterior length of the crypt has been defined in this manner the same bur is used to make a vertical cut through the external plate at its anterior margin. A second cut through the outer plate is made at the posterior end of the crypt at an angle of 45° from the row of trephine holes (*Fig.* 1C). A chisel is used to outfracture the buccal plate which is then picked out of the wound with a curved haemostat, exposing the crown of the third molar lying in its crypt (*Fig.* 1D). A Warwick James elevator is applied to the occlusal surface of the tooth and used to

deliver it (*Fig.* 1E). If difficulty is experienced it is usually overcome by the further removal of bone at the distal and lower corner of the bony window. Any follicular remnants are removed, the bone margins are smoothed with a ' vulcanite bur ', and the wound is closed with two or three sutures (*Fig.* 1F). As the operation takes only a few minutes to perform both sides can be treated under the same anaesthetic.

Most patients experience some postoperative swelling and a variable degree of trismus which usually subsides in 2 or 3 days. A few complain of soreness in the immediate postoperative period, but pain severe enough to require the use of analgesics is uncommon. In most instances the sutures are removed on the seventh postoperative day. Care should be taken to account for and remove all of the sutures, for in 3 cases in this series chronic infection in the postoperative period was associated with the presence of a retained suture.

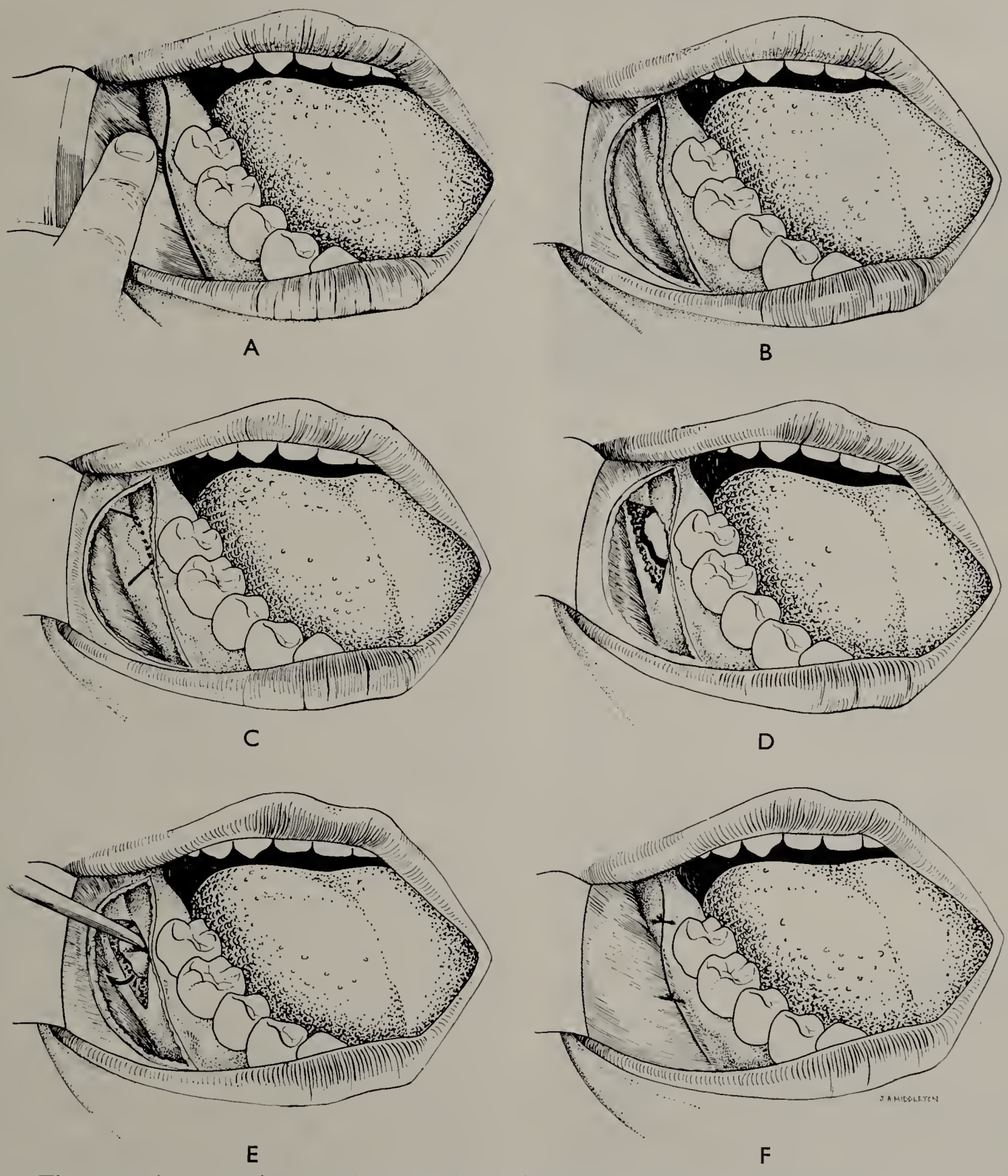


Fig. 1.—The operative procedure employed in this series was a modification of Bowdler Henry's ' lateral trepanation ' technique.

RESULTS

To date, 125 teeth have been removed using this method (*Table I*). Forty-three patients

(83 extractions) have been followed up for a period of more than 3 months and of these, 26 patients (50 extractions) have been followed up for more than 1 year after the operation. As there was no change apparent in the results later than 3 months after the operation, this group of patients has been analysed without further subdivision (*Table II*).

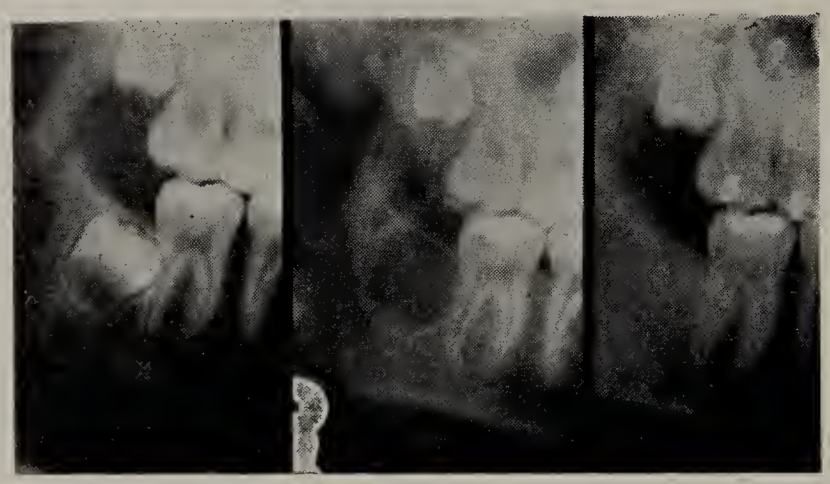


Fig. 2.—Radiographs of the third molar area 1 month before and 1 week and 15 months after removal of the third molar by the lateral trepanation procedure described.

Table I.—Numbers of Patients treated by Lateral Trepanation

	No. of Patients	*No. of Teeth*
Total number of patients	64	125
Followed up for more than 3 months postoperatively	43	83
Followed up for more than 1 year postoperatively	26	50

Table II.—Periodontal Results Assessed at least 3 Months after the Operation

	No. of Teeth	
	Good	*Fair*
State of hard tissue	83	0
Condition of soft tissue	75	8

Results were assessed under two main headings, namely, the state of the hard tissue and the condition of the soft tissues, respectively (*Table II*).

Hard-tissue results were assessed as satisfactory when there was no damage to the second molar, when bone healing was complete, and when there was no alveolar bone-loss either distal to or buccal to the second molar (*Fig.* 2).

The soft-tissue result was assessed as satisfactory when there was no evidence of gingival recession or pocket production in relation to the second molar. In all cases a linear scar was visible but this was usually unobtrusive and should not have any deleterious effect on the long-term dental health of the patient. Following the removal of 8 teeth the condition of the soft tissues was considered to be only fair. These were all cases early in the series in whom the incision had been made much too close to the gingival margin of the second molar which had either become involved in the scar or distorted by scar contraction. However, it should be said that in no instance was there any reason to believe that the long-term periodontal health of the patient would be adversely affected, and experience has shown that this can be avoided by correctly siting the incision.

DISCUSSION

The technique of lateral trepanation is a useful method of removing lower third molars which are almost certain to become impacted. It is best performed when the third molar crown is almost complete and before root formation has commenced. The procedure offers a time advantage in relation to enucleation at an earlier stage of third molar tooth germs in that the prediction of impaction and the estimate of the dental status of the older patient is likely to be more reliable.

When the removal of impacted third molars is delayed until their roots are more than two-thirds formed, as is common practice with conventional surgical techniques, then surgical, periodontal, and occlusal problems may arise. These complications can largely be avoided by the lateral trepanation of third molars at a time when it is usually possible to determine whether or not they will become impacted but before they can have had adverse effects on the dental health of the patient.

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THE EFFECTS OF VARIATIONS IN TOOTH MORPHOLOGY AND POSITION ON ERUPTION

D. D. DI BIASE, B.D.S., F.D.S., D.Orth.

*Senior Registrar in Orthodontics, The London and Whipps Cross Hospitals**

INTRODUCTION

A problem which often confronts the orthodontist is that of predicting the eruption pattern of a misplaced permanent tooth. Diagnosis and treatment in this type of case are based not only on the nature of the underlying cause but also on the influence of any other features which might effect further eruption. When these become adverse, management may be both complex and lengthy if eruption is to be achieved, and not infrequently the removal of an erupted tooth is essential to provide sufficient space. It is for these reasons that all the features which might influence eruption should be accurately assessed. Any spontaneous changes which might occur are particularly important, for on their recognition depends the simplicity of operative procedures. Whilst some might be motivated to routine surgical exposure and fixed attachments, orthodontists generally recognize the value of spontaneous change and utilize it in treatment planning.

With the motivating forces that govern normal eruption still a mystery, any assessment on the eruption rate and pattern is based on those features which have become significant in the history of clinical practice. Apart from specific causes such as trauma and pathology, these are largely associated with variations in the morphology and position of the unerupted tooth and related structures. Following the elimination of pathology, subsequent tooth eruption is still based on these anatomical features.

Whilst it is important to determine accurately the significance of each feature it is not always a straightforward procedure. The very methods available at present suffer from limitations in both localization and standardization. It is, therefore, hardly surprising that much of what has been written in standard works is the result of subjective appraisal. Limitations in the accuracy of radiography have been pointed out by a number of authorities (Franklin, 1952; Hallet, 1959), and though combinations of radiographic views at differing planes and angles improve these problems still arise. Obviously, experience and ability increase the quality of the interpretation, but even the most accomplished would agree about the difficulties.

Clinical research also suffers from the difficulty of evaluating routine case records. To overcome some of these Hallet and Burke (1961) adopted a method of subjective ranking in their analysis of the occlusion in cases where first permanent molars had been extracted. In assessing the eruption and alinement pattern others have been prompted, using such a system, to suggest limiting values for some types of tooth displacement. Whilst criticisms may be levelled at the accuracy of some measurements, they at least provide ' a clinical yardstick ', and information of this type helps to avoid some of the pitfalls of misjudgement.

REVIEW OF THE LITERATURE

Variations in the anatomy of the tooth have naturally formed a large part of any investigation on eruption, and the development of these structures contributes to some of the basic theories on the forces which govern normal eruption.

1. Tooth Structure

By far the greatest volume of work dealing with the effects of anatomical variation is concerned with root structure, both formation and morphology. Elongation of the developing root is amongst the earliest theories of tooth eruption.

Constant (1896) quotes the views of Thomas Bell (1835): ' As ossification proceeds the roots

* Present address: Consultant Orthodontist, Southend-on-Sea Hospital.

Chapman Prize Essay presented at the meeting held on 8 February, 1971.

of teeth continue to elongate until they can no longer be contained within the alveoli.'

Since that time arguments have ranged for and against this theory. It is well known clinically, however, that teeth with either formed or stunted roots will erupt and Massler and Schour (1941), in a survey, and Berkovitz and Thomas (1969), from experimental work, have shown that root resection of the rodent incisor has little effect on the eruption rate. Main and Adams (1966), using drugs to depress the mitotic activity of the developing pulp, also found little change in the eruption rate of teeth with limited growth.

From a study of the eruption rate of 22 central incisors which had been surgically exposed, Burke (1963) found that blunting and premature closure of the apices were presenting features when the eruption rate was slow. He considered that root curvature could affect the eruption rate, and concluded that straight roots and open apices were important factors in normal eruption. Broadway and Gould (1960) considered that root curvature in the presence of trauma could cause delayed eruption of the incisor. Whilst Howard (1966), in a study on the eruption of 42 central incisors, where supernumeraries had been removed from the cases, found only 1 case where root morphology appeared to affect subsequent eruption.

2. Tooth Position

Displacement and failure of tooth eruption frequently occurs in the jaws, particularly with lower third molars. Though removal of these teeth is often indicated, their eruption pattern has been investigated where the adjacent molars have been extracted as part of orthodontic treatment.

Cryer, in his study in 1967, found that the degree of inclination of the third molar was a limiting factor on the eruption pattern, whilst the depth of displacement was less important. Breakspear (1966) considered that migration of the lower third molar was entirely axial and uprighting of the tooth did not occur until contact was made with the adjacent first molar.

Palatal displacement with failure of the maxillary canine to erupt is well recorded and Hovell (1966) considered the mesial inclination that occurred during development an important factor in the aetiology. The variable eruption pattern of the central incisor following the removal of a supernumerary has also led authorities to suggest that other factors might be involved. Gardiner (1961) noted that labial displacement of the incisor was associated with delayed eruption, and Howard (1966) stressed the limiting effects of apical displacement.

3. Spacing and Crowding

Impaction of the canine was said by Hitchin (1951) to be due to inadequate development in the size of the dental arch, but Dewel (1949) had shown that crowding was not a significant feature, and in many cases impaction of the canine occurred with normal arch form.

The importance of sufficient space for eruption is recorded in most reports on unerupted incisors. Burke (1963) found that the rate of incisor eruption was interrupted in the presence of crowding. On space being created by extractions the eruption rate was restored even if the incisor was labially displaced. As regards the amount of space for eruption, Willcocks (1966) considered that it should be at least 2 mm. greater than the width of the unerupted incisor crown.

Most of the investigations into delayed eruption have dealt with only a limited number of variables, and the relative significance of each feature is not fully understood. Investigations have also dealt mainly with the occlusal movement of the tooth, when it is well known that changes can occur in other planes. The present study differs from others in as much as it evaluates a large number of variables in an attempt to determine their relative effects on eruption. It also investigates some of the spontaneous changes that occur during migration and eruption.

MATERIALS AND METHOD

Two methods were used. The first was a non-parametric survey to determine the anatomical variations associated with delayed eruption and their effects on the period of migration to eruption. The second was a parametric analysis of serial occlusal radiographs to determine more specifically some of the changes in tooth position during eruption.

The sample consisted of a series of cases where central incisors were associated with a supernumerary. These were obtained from the records of over 7000 consecutive patients examined in four North-east Metropolitan Regional Orthodontic Departments during the period 1960–7. The use of this type of case enabled both supernumerary and anatomical features to be examined in relation to incisor eruption. Data were obtained from the records of 165 cases and a method of subjective grading was employed to determine certain features using clinical and surgical notes, lateral oblique, anterior occlusal, intra-oral, and true lateral radiographs, and study models.

The data were recorded on a questionnaire basis where each question related to a group of variable features. Double determination was used in the examination and where discrepancies occurred further examinations were made until two consecutive similar findings were obtained.

By using the maxillary midline suture as a radiographic landmark it was possible to record separately data for right and left central incisors in each case. In this way not only were the

number of variables reduced to manageable proportions but also three comparative groups were formulated to determine the features associated with the unerupted incisor:—

Group A. Erupted incisor associated with a supernumerary.

Group B. Erupted incisor not assocated with a supernumerary.

Group C. Unerupted incisor.

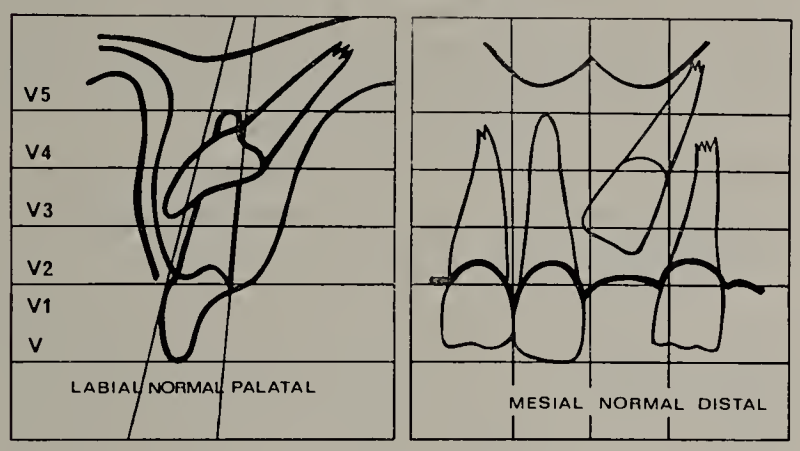


Fig. 1.—Relationships. V, Full incisor eruption. V_1, Partial eruption. V_2, V_3, V_4, Thirds of the normal incisor root position. V_5, Apex of incisor.

A total of 45 features with 197 variable features were recorded twice for each group to give 330 sets of data for analysis, and both the groups and features were numbered progressively. The following features were used for this paper:—

1. *Root Structures*

a. Root formation

Root formation was related to whether the apex was open or closed as seen on the radiographs and also whether the amount of root formation on the incisor was normal when compared with the adjacent teeth. Where the apex was open on a tooth associated with a supernumerary it was important to ensure that it was capable of later forming root structure.

b. Root morphology

When recording data about root morphology the term 'dilaceration' was avoided and variations were expressed in simple morphological terms.

2. *Tooth Position*

Recordings were made in each plane and the relationships used are shown in *Fig.* 1.

a. Labiopalatal

Displacement and inclination were recorded together in one group.

b. Vertical

The position of the unerupted incisor was related to the normal incisor position by dividing its length. Where both incisors were unerupted the relationship was obtained by repositioning a template.

c. Mesiodistal

Bodily displacement and inclination were recorded in separate groups and where an incisor was displaced and tipped the degree of bodily displacement was obtained by mentally uprighting the tooth.

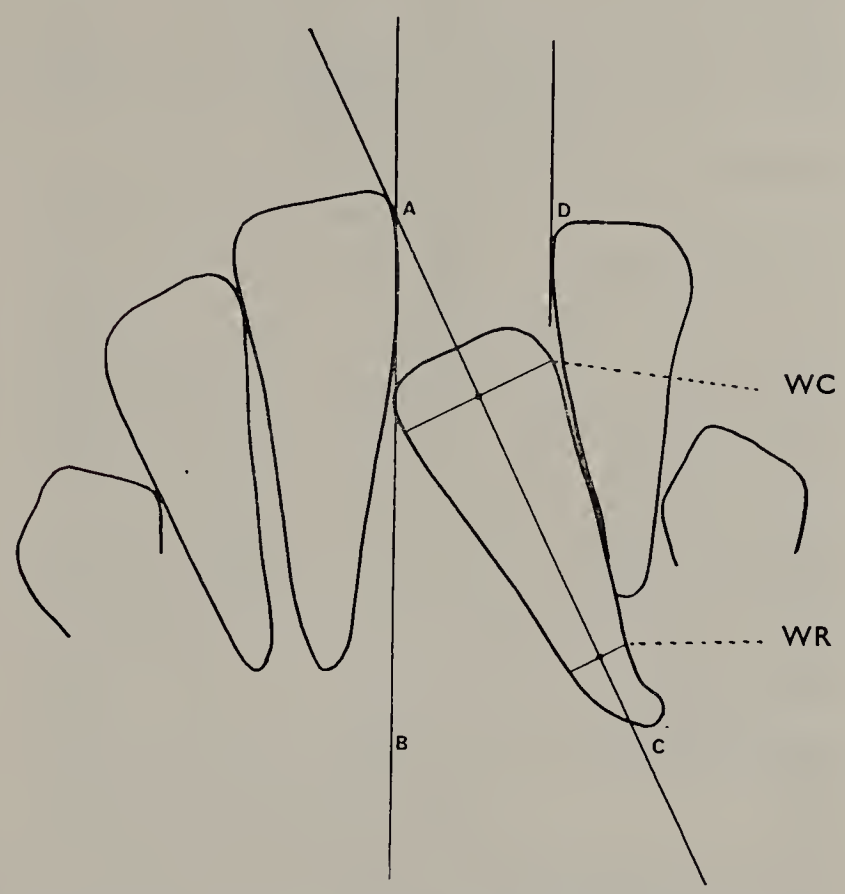


Fig. 2.—Interpretation of occlusal radiograph tracings. AB, Midline maxillary suture. AC, long axis of incisor. BAC, Angle of incisor to midline. AD, Space for incisor eruption (mm.). WC, Maximum width of incisor crown. WR, Width of apical third incisor root. The long axis of the incisor was obtained from the midpoints of WC and WR. The correction in eruption space =AD−WC+9. The value 9 was the average incisor width in millimetres. In bilateral unerupted $\underline{1|1}$ cases, point A was taken at the midline, and in unilateral cases at the mesial margin of the erupted central incisor.

3. *Crowding and Spacing*

Crowding and spacing were recorded generally throughout the maxillary arch and particularly in the labial segment where loss of space indicated that the distance between adjacent erupted incisors was less than the radiographic width of the unerupted incisor crowns.

4. *Age*

Ages ranged from $6\frac{1}{2}$ to 14 years and these were divided into two groups to see whether any particular features differed with age.

The data were transferred to punch tape and an Elliott 803 computer was programed to record the total distribution of each feature and to detect correlations between the features and the eruption

pattern. A progressive numbering system enabled input data to be accurately checked during computer programing and incorrectly punched data were thereby rejected. The computer produced arrays of associated features which, after having been examined visually, were tested statistically for any significance of association, using the χ^2 test on the basis of the null hypothesis and incorporating Yates' (1934) correction for the smaller binomial distributions.

Table I.—Computer Arrangements and χ^2 Correlation Test of Root Formation with Incisor Eruption Groups

Root Apex	Incisor Eruption Group			
	A	*B*	*C*	Total
Open normal	45	42	37	124
Closed normal	68	70	26	164
Open reduced	6	1	25	32
Closed defective	2	2	6	10
Open normal	45	—	37	82
Open reduced	6	—	25	31
Total	51	—	62	113

2×2 arrangement for χ^2 test.

Table II.—Computer Arrangements and χ^2 Correlation Test of Root Formation with Incisor Eruption Groups

Incisor Root Morphology	Incisor Eruption Group			
	A	*B*	*C*	Total
Normal limits	108	103	62	273
Curved	4	7	11	22
Apex curved	3	0	10	13
Defective	6	5	11	22
Normal limits	108	—	62	170
Curved and defective	13	—	32	45
Total	121	—	94	215

2×2 arrangement for χ^2 test.

Analysis of Occlusal Radiographs

Changes in the mesiodistal position were analysed during the migration and eruption period from serial tracings of standardized occlusal radiographs. These were obtained from 28 incisors (20 cases) where X-rays were taken at 6-monthly intervals after removal of the supernumerary using the following technique.

An occlusal film was held gently between the teeth of a patient, who was seated upright in a dental chair. The head was adjusted until the film was lined with markers. The tube was placed 1 cm. above the bridge of the nose at an angle of 75° (Ingram, 1950), and an exposure of 0·5-second 13 MA. 60 kV. was given. The patient was protected throughout with a plastoled apron.

Each radiograph was traced twice and the landmarks, planes, and angles that were examined are shown in *Fig.* 2. The angle between the maxillary midline and the long axis of the unerupted incisor was measured, together with incisor width and eruption space. A correction was made in the eruption space to account for variations in the width of the unerupted incisor crowns.

The reliability of the tracing method was tested by calculating the standard error of the difference between measurements from the first and second tracings, using the method of Moroney (1951). These were tested for statistical significance with Student's *t* test. As no significance could be found and all the measurements fell within 2 standard errors the reliability of the tracing method was established.

The reliability of the radiographic technique was tested by tracings of 2 occlusal radiographs taken on separate occasions from 10 randomly chosen adults. The standard error between the measurements of first and second radiographs were calculated as described above. As these also fell within 2 standard errors of the tracing method the reliability of the technique was established.

RESULTS

Correlation of Groups of Anatomical Features and Eruption State

1. *Root Structures*

a. Root formation

Both complete and incomplete root structures were found on unerupted incisors. One radiographic feature particularly associated with the unerupted incisor was that of a relatively reduced root formation when the incisor apex was open. There was an association between reduced root formation and the unerupted incisor ($\chi^2 = 11{\cdot}3$, which is significant at the 0·1 per cent level; *Table I*).

b. Root morphology

Root curvature and defective root morphology were significantly associated with the unerupted

incisor ($\chi^2=11{\cdot}0$, which is significant at the 0·1 per cent level; *Table II*).

2. *Displacement and Inclination*

a. Labiopalatal

Labial displacement and labial inclination were significantly associated with the unerupted incisor ($\chi^2=60{\cdot}2$, which is significant at the 0·1 per cent level; *Table III*).

Table III.—Computer Arrangements and χ^2 Correlation Test of Incisor Position and Inclination with Incisor Eruption Groups

Incisor Position and Inclination	Incisor Eruption Group			
	A	*B*	*C*	Total
Labial+	13	0	18	31
Labial	28	7	59	94
Normal limits	69	102	15	186
Palatal	11	6	2	19
Labial+ and labial	41	—	77	118
Normal and palatal	80	—	17	97
Total	121	—	94	215

2×2 arrangement for χ^2 test.

Table IV.—Computer Arrangements and χ^2 Correlation Test of Incisor Position with Incisor Eruption Groups

Incisor Position	Incisor Eruption Group			
	A	*B*	*C*	Total
Mesial	3	2	6	11
Normal limits	59	106	23	188
Distal	59	7	65	131
Mesial and distal	62	—	71	133
Normal limits	59	—	23	82
Total	121	—	94	215

2×2 arrangement for χ^2 test.

b. Mesiodistal (displacement)

Bodily displacements, both mesial and distal, occurred in association with the unerupted incisor. These were most frequently distal and were significantly associated with the unerupted incisor ($\chi^2=12{\cdot}86$, which is significant at the 0·1 per cent level; *Table IV*).

c. Mesiodistal (inclination)

Both mesial and distal inclinations were significantly associated with the unerupted incisor ($\chi^2=11{\cdot}1$, which is significant at the 0·1 per cent level; *Table V*).

d. Vertical

The height of the crown of the unerupted incisor varied, but positions above V4 were rare,

Table V.—Computer Arrangements and χ^2 Correlation Test for Incisor Inclination with Incisor Eruption Groups

Incisor Inclination	Incisor Eruption Group			
	A	*B*	*C*	Total
Mesial	41	24	56	121
Normal limits	49	82	18	149
Distal	31	9	20	60
Mesial and distal	72	—	76	148
Normal limits	49	—	18	67
Total	121	—	94	215

2×2 arrangement for χ^2 test.

the majority occurring between V2 and V3. Variations in incisor height showed no significant change with age ($\chi^2=2{\cdot}5$, which is not significant).

e. Rotations

Rotations occurred with both erupted and unerupted incisors. These were not significantly associated with the unerupted incisors but there was a significant association with the erupted incisor in group B ($\chi^2=4{\cdot}5$, which is significant at the 5 per cent level).

3. *Crowding and Spacing*

a. Crowding of dental arches

Though crowding often occurred when the incisor was unerupted no significant association could be found.

b. Loss of space

Loss of space for incisor eruption was significantly associated with the unerupted incisor ($\chi^2=80{\cdot}9$, which is significant at the 0·1 per cent level).

Correlation of Features associated with Delayed Eruption and the Period of Migration to Eruption

Cases were used where treatment had been followed for at least 2 years. After excluding cases who had been under treatment for a shorter

period of time and cases where either treatment was discontinued or the incisor was removed, a total of 68 incisors remained in this section. The analysis was made by correlating the group of incisors where eruption had occurred in 1 year with those where eruption had occurred in over 1 year. A reassessment of the space for eruption was made at the 1-year stage.

Table VI.—Computer Arrangements and χ^2 Correlation Test for Root Morphology with Migration Period to Eruption

Root Morphology	Migration Period to Eruption*					
	1 year	1–2 year	+2 year	E	F.E.	Total
Normal limits	21	14	3	7	4	49
Curved	2	3	2	1	1	9
Apex curved	3	1	0	2	1	7
Defective	1	1	0	1	0	3
Normal limits	21	28				49
Curved and defective	6	13				19
Total	27	41				68

2×2 arrangement for χ^2 test.
* E=Exposure after 1 year. F.E.=Failure of eruption.

Table VII.—Computer Arrangements and χ^2 Correlation Test for Incisor Position and Inclination with Migration Period to Eruption

Incisor Position and Inclination	Migration Period to Eruption					
	1 year	1–2 year	+2 year	E	F.E.	Total
Labial+	4	4	2	4	2	16
Labial	13	13	2	7	4	39
Normal limits	8	2	1	0	0	11
Palatal	2	0	0	0	0	2
Labial+ and labial	17	38				55
Normal and palatal	10	3				13
Total	27	41				68

2×2 arrangement for χ^2 test.

1. *Root Structures*

a. Root formation

The period of migration to eruption was not significantly affected by the amount of root formation ($\chi^2=0{\cdot}06$, which is not significant).

b. Root morphology

Though there was a tendency for curvatures to occur slightly more frequently in groups with a longer migration period, the period of migration was not significantly associated with variations in root morphology ($\chi^2=0{\cdot}52$, which is not significant; *Table VI*).

2. *Displacement and Inclination*

a. Labiopalatal

A longer period of migration to eruption was associated with labial displacement and inclination ($\chi^2=8{\cdot}5$, which is significant at the 1 per cent level; *Table VII*).

b. Mesiodistal (displacement)

A longer period of migration to eruption was associated with mesial and distal displacement

Table VIII.—Computer Arrangements and χ^2 Correlation Test for Incisor Position with Migration Period to Eruption

Incisor Position	Migration Period to Eruption					
	1 year	1–2 year	+2 year	E	F.E.	Total
Mesial	1	1	1	0	0	3
Normal limits	12	2	1	2	1	18
Distal	14	16	3	9	5	47
Mesial and distal	15	35				50
Normal limits	12	6				18
Total	27	41				68

2+2 arrangement for χ^2 test.

($\chi^2=5{\cdot}97$, which is significant at the 5 per cent level; *Table VIII*).

c. Mesiodistal (inclination)

A longer period of migration to eruption was associated with mesial and distal inclinations ($\chi^2=13{\cdot}2$, which is significant at the 0·1 per cent level; *Table IX*).

d. Vertical

The period of migration to eruption was associated with the degree of vertical displacement. The more deeply placed incisors erupted

later than those more superficially placed (χ^2= 13·92, which is significant at the 0·1 per cent level; *Table X*).

3. *Space for Eruption*

The period of migration to eruption was affected by the space between adjacent erupted incisors. When this was ample, eruption occurred earlier than when it was inadequate (χ^2=15·91, which is significant at the 0·1 per cent level; *Table XI*).

Table IX.—Computer Arrangements and χ^2 Correlation Test for Incisor Inclination with Migration Period to Eruption

Incisor Inclination	Migration Period to Eruption					
	1 year	1–2 year	+2 year	E	F.E.	Total
Mesial	9	11	3	10	5	38
Normal limits	12	3	0	0	0	15
Distal	6	5	2	1	1	15
Mesial and distal	15	38				53
Normal limits	12	3				15
Total	27	41				68

2×2 arrangement for χ^2 test.

Table X.—Computer Arrangements and χ^2 Correlation Test for Incisor Position with Migration Period to Eruption

Incisor Position	Migration Period to Eruption					
	1 year	1–2 year	+2 year	E	F.E.	Total
V_1	3	0	0	0	0	3
V_2	20	10	0	3	1	34
V_3	4	7	4	6	5	26
V_4	0	2	1	2	0	5
V_1–V_2	23	14				37
V_3–V_4	4	27				31
Total	27	41				68

2×2 arrangement for χ^2 test.

Spontaneous Changes in the Incisor Position during Migration and Eruption

1. *Labiopalatal*

Changes in labiopalatal position were investigated by correlating the original displacement with the alinement on eruption, and this was then related to the space for eruption.

Table XI.—Computer Arrangements and χ^2 Correlation Test for Space for Eruption with Migration Period to Eruption

Space for Eruption	Migration Period to Eruption					
	1 year	1–2 year	+2 year	E	F.E.	Total
Ample space	7	6	0	1	0	14
Adequate space	20	10	1	3	1	35
Inadequate space	0	3	4	7	5	19
Ample and adequate	27	22				49
Inadequate	0	19				19
Total	27	41				68

2×2 arrangement for χ^2 test.

Table XII.—Computer Arrangements and χ^2 Correlation Test for Space for Eruption with Changes in Labiopalatal Position

Space for Eruption	Changes in Labiopalatal Position*			
	S.A.	S.I.	N.I.	Total
Ample space	6	4	0	10
Adequate space	11	11	4	26
Inadequate space	0	6	7	13
Ample and adequate	32		4	36
Inadequate	6		7	13
Total	38		11	49

2×2 arrangement for χ^2 test.
* S.A.=Spontaneous alinement. S.I.=Some improvement. N.I.=No improvement.

The labially placed incisor improved spontaneously during the period of migration to eruption. This was significant in cases where

space was either adequate or ample ($\chi^2=8{\cdot}1$, which is significant at the 1 per cent level; *Table XII*).

2. *Mesiodistal*

Changes in angulation occurred in nearly all cases during migration, uprighting being more evident when the space for eruption was greater than the width of the incisor crown. The changes in angulation between the initial and yearly radiographs were plotted against the space for eruption shown on the yearly radiograph in the form of a scatter diagram (*Fig.* 3). A relationship was found between changes in angulation and space for eruption, and this was tested for significance by dividing the results into two arbitrary groups. The changes in angulation in a low-space group *A* where the space for eruption was 9 mm. or less were compared with a larger space group *B*, using Student's *t* test, and were found to be significant at the 0·1 per cent level ($t=4{\cdot}3$).

Finally, the changes in tooth position from the series of radiographs of each case were recorded by superimposition tracings using the

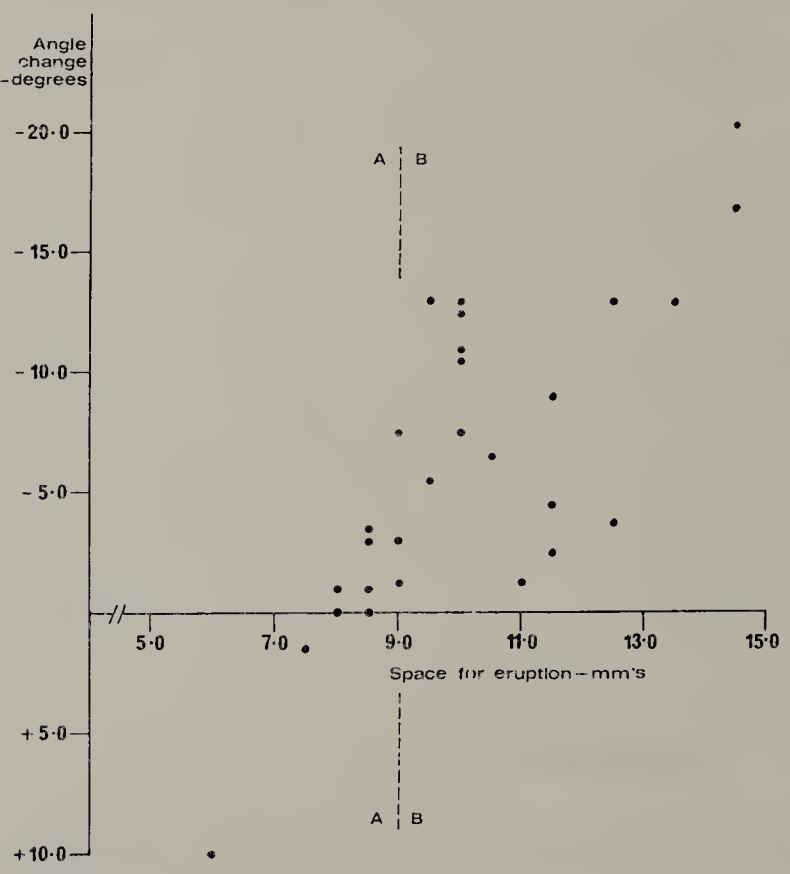


Fig. 3.—Scatter diagram of the relationship between change in incisor angulation and the corrected eruption space. Values in A and B correspond to the two groups which were tested statistically for the significance of association between these features.

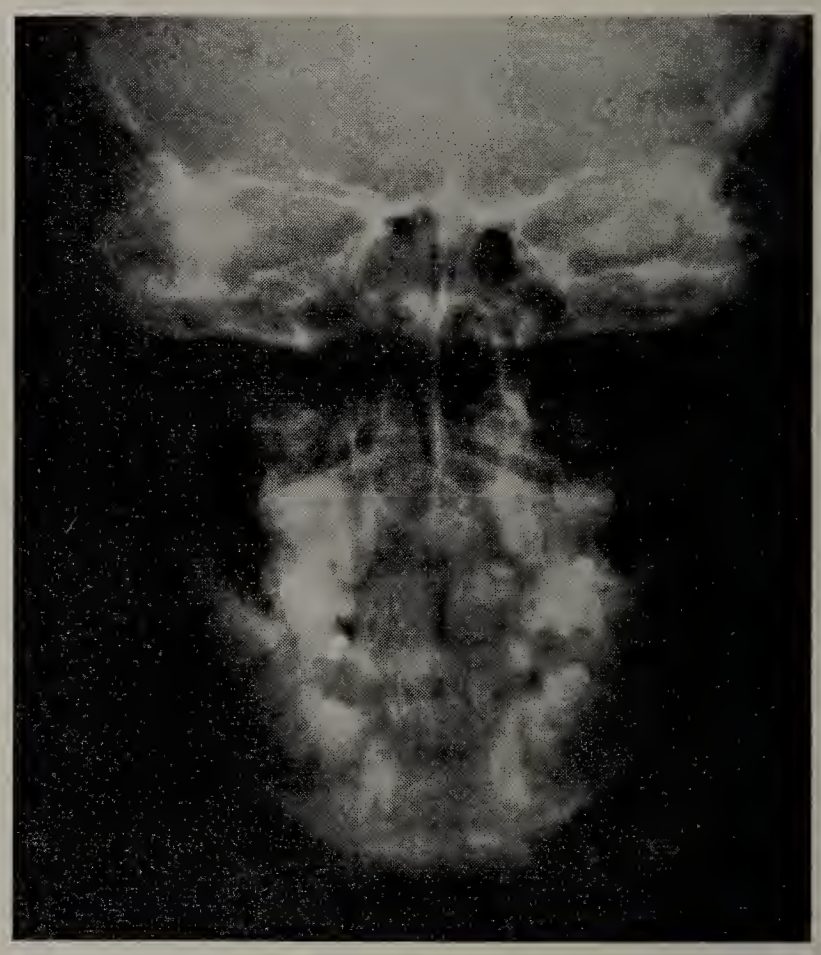
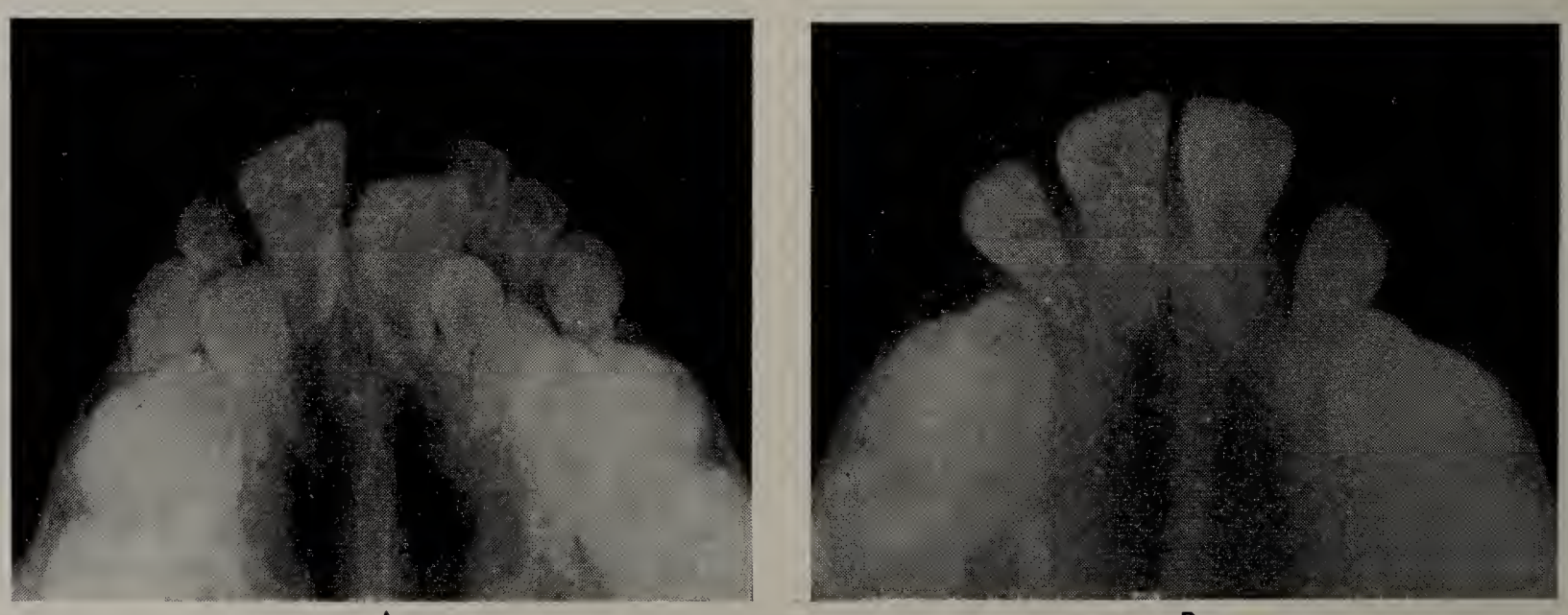


Fig. 4.—Postero-anterior radiograph of the skull of a boy aged 9 years 2 months, showing a relatively reduced root formation on $\underline{|1}$ with a raised floor of the left nasal cavity.



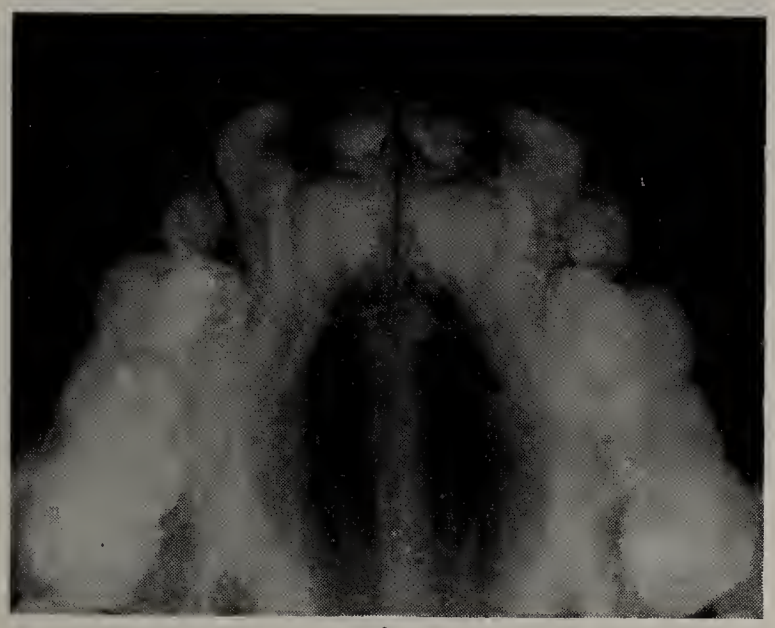
A B

Fig. 5.—Occlusal radiographs of a girl in whom spontaneous eruption and alinement of $\underline{|1}$ occurred in the presence of root curvature. A, Aged 8 years 5 months, before removal of the supernumerary and extraction of $\underline{\text{CB|BBC}}$. B, Aged 9 years 11 months, showing that spontaneous eruption and alinement of $\underline{|1}$ has occurred.

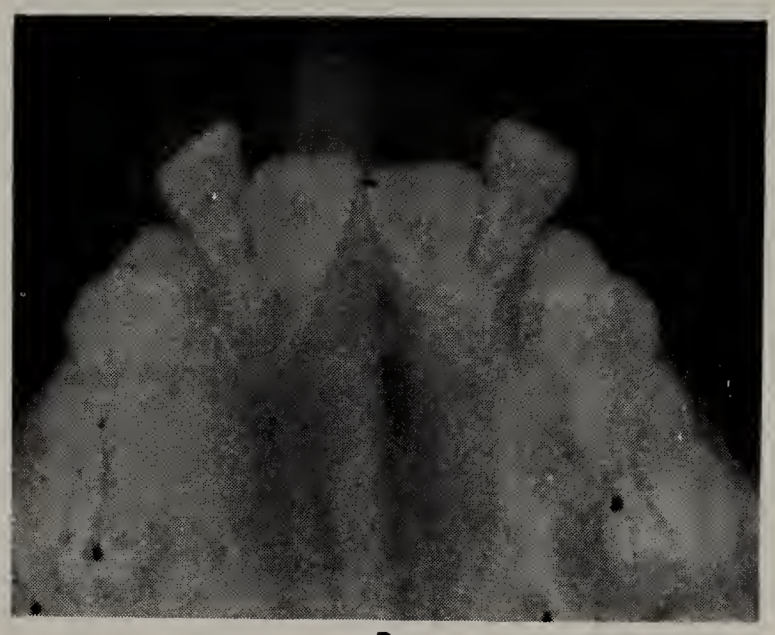
maxillary midline and erupted incisal edges as fixed points. These indicated that where the displaced incisor was inclined either mesially or distally the eruption path was not straight but curved.

DISCUSSION

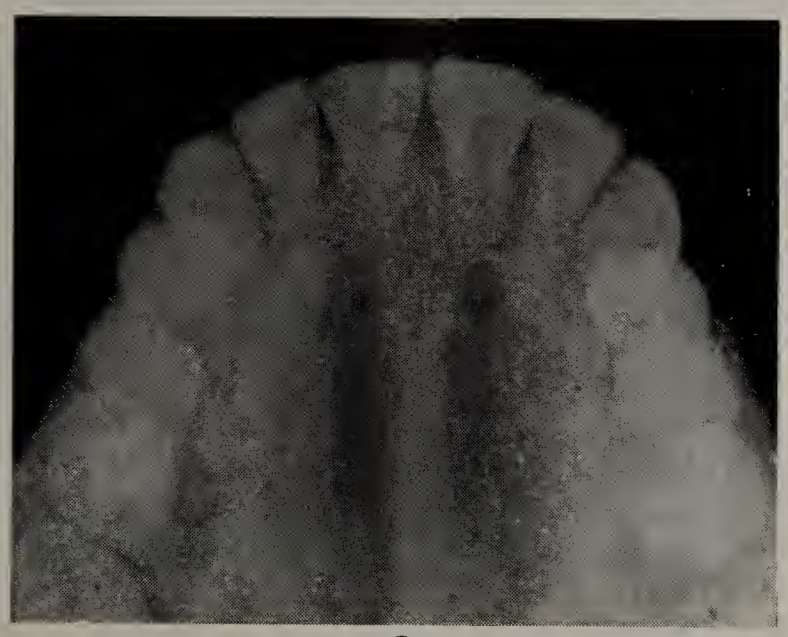
Any evaluation of the findings must be related to the limitations of radiographic interpretation.



A



B



C



D

Fig. 6.—A girl in whom spontaneous eruption and alinement occurred following the removal of supernumeraries, the extraction of $\underline{C|C}$, and movement of $\underline{2|2}$ distally. Occlusal radiographs: (A) at the age of 8 years 2 months, before removal of the supernumeraries; (B) at 9 years 4 months, showing the eruption of $\underline{1}|$; (C) 4 years after eruption of $\underline{1|1}$, with slight displacement of $\underline{1}|$ apex. D, Photograph of the alinement of $\underline{21|12}$ at 14 years 2 months.

The occlusal view, though standardized, produces only a 75° image, and the changes in root length which occur as the tooth changes position cannot be accurately assessed.

The results do show, however, that certain anatomical features are distinctly associated with delayed eruption and that they are mainly localized to the unerupted incisor and adjacent structures. General features such as Angle's type of malocclusion and dental base appear to play little part, and crowding of the dental arches, though not significantly associated with delayed eruption, has considerable importance on the subsequent migration and eruption pattern.

The distribution of features that occurred during correlations suggests that although a variety of features are significantly associated with failure of eruption, the overall effect in any case is a combination of these.

The Root Structures

Both complete and incomplete roots were found on the unerupted incisors but any significant effect on the eruption period was not proved. One feature which did appear was the tendency for unerupted incisor roots with open apices to have a relatively reduced formation. This was also noted by Day (1946) and could be an indication of the limiting effects of the skeletal framework on root formation (*Fig.* 4).

Varying degrees of root curvature and blunted root structures were associated with the unerupted incisor. However, their effects on the eruption period appeared to be negligible. In fact, both eruption and spontaneous alinement could occur in the presence of marked curvatures (*Fig.* 5).

These findings, though contrary to some of the accepted views, do indicate further the possible secondary role of root structures on the eruptive processes.

to eruption. The significance of labial displacement and inclination was reduced at the 1 per cent level, whilst mesiodistal displacement was significant at only the 5 per cent level. It could be that bodily displacement mesiodistally has less influence on eruption than other types of displacement. Inclination mesiodistally, however, remained at the highly significant 0·1 per cent level, and when accompanied by displacement of both crown and apex gave rise to angular

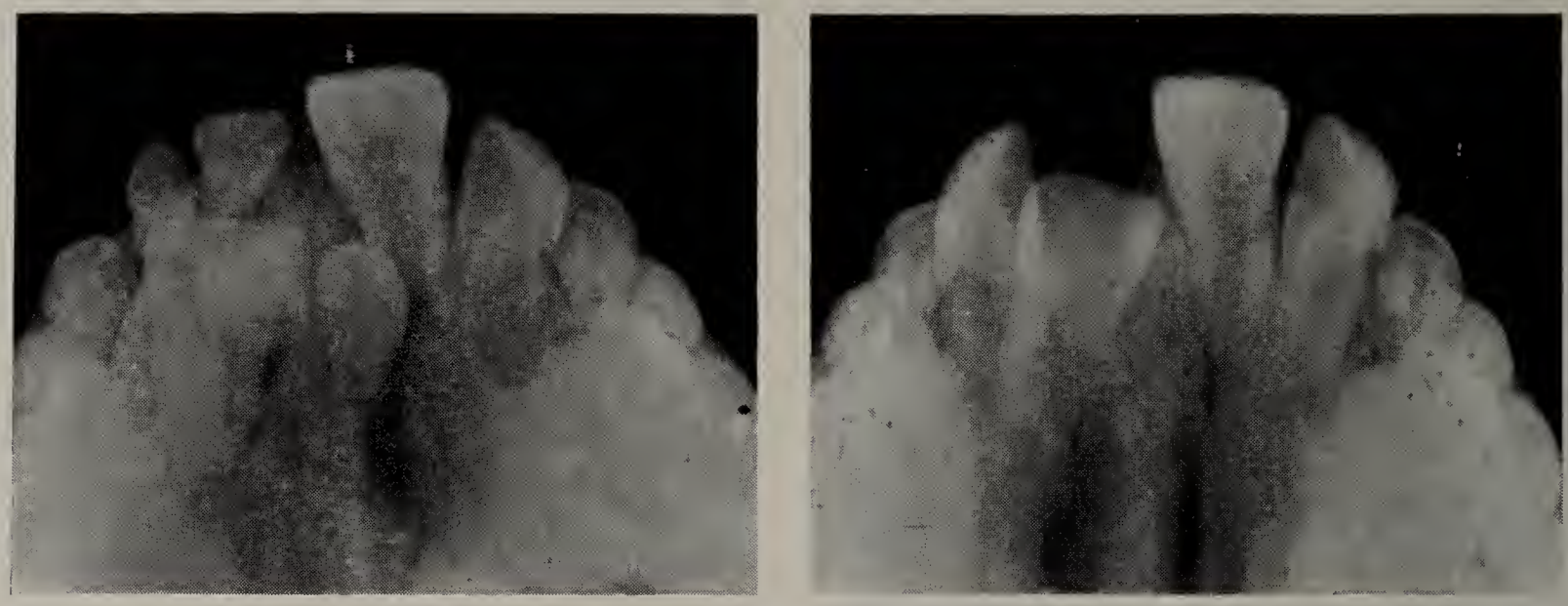


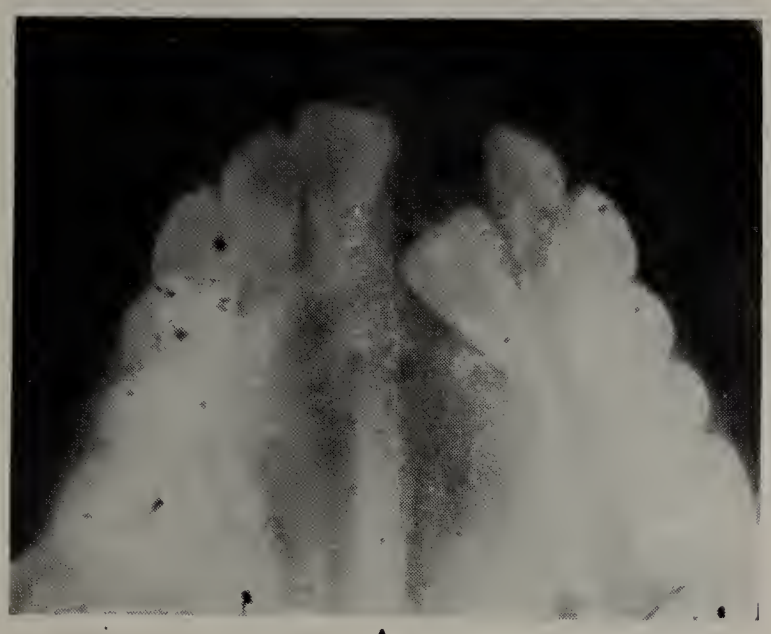
Fig. 7.—A boy with unerupted $\underline{1}|$. Occlusal radiographs: (A) at the age of 7 years 10 months, before removal of the supernumeraries; (B) at 8 years 10 months, with loss of space and increase in angulation of $\underline{1}|$; (C) at 10 years 5 months, showing spontaneous eruption and alinement of $\underline{1}|$ following the creation of space. D, Intra-oral photographs showing the diastema of $\underline{1|1}$ at 10 years 5 months (*left*) and at 11 years 4 months (*right*). E, Tracings from (B) and (C).

Tooth Displacement

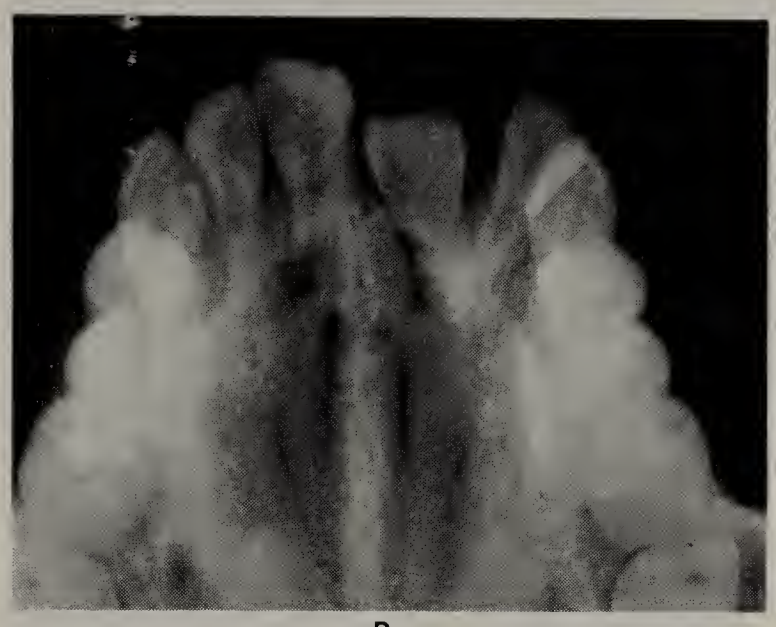
Displacement and inclinations which were associated with failure of eruption at the highly significant 0·1 per cent level were far more variable when correlated with the period of migration impactions with adjacent teeth. If it is accepted that the greatest eruptive force is axial, then any abnormality in the inclination of a tooth during development could be of great significance in contributing to delayed eruption.

The degree of vertical displacement, as might logically be expected, was directly related to the length of the eruption period; the higher the incisor crown, the longer its eruption period. As tipping of the incisor was often found when the tooth was deeply situated this could reflect the importance of inclination on vertical development.

took place (*Figs.* 7, 8), whilst in cases where space loss continued the angulation occasionally increased (*Fig.* 9). Movement appeared to occur initially at the apical third of the unerupted incisor root and commenced only when sufficient space has been created. The space required could be estimated from the original occluded radiograph by mentally uprighting the unerupted



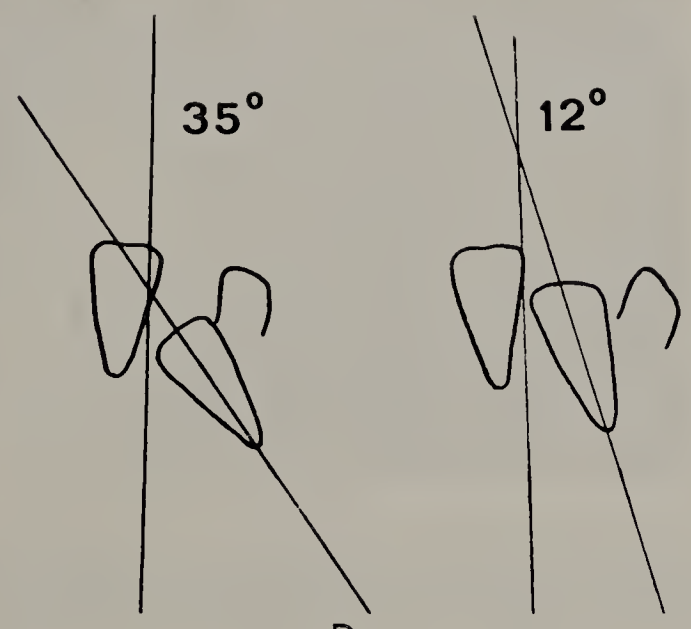
A



B



C



D

Fig. 8.—A girl with an unerupted $\underline{|1}$. Occlusal radiographs: (A) at the age of 12 years 7 months, after removal of the supernumerary; (B) at 13 years 11 months, at the time when $\underline{|1}$ had penetrated the mucosa, showing considerable decrease in the angulation of $\underline{|1}$. C, Study model taken at 14 years 8 months. D, Tracings from (A) and (B).

Space for Eruption and Changes in Incisor Position

Loss of space for the unerupted incisor, whether due to crowding or to drifting of the adjacent teeth, was significantly associated with a longer eruption period, and in cases where space was not created, spontaneous eruption rarely occurred. Though earlier eruption tended to occur where displacements were slight, considerable changes could occur in the presence of marked displacement and inclination (*Fig.* 6) if sufficient space was created. The importance of this is seen from the relationship between space and change in angulation (*Fig.* 3). In cases where space was ample, uprighting of the incisor

incisor about its apical third. The distance the crown travelled indicated how much more space than the crown width was necessary. Once uprighting had commenced it seemed to continue in the absence of the guiding influence of adjacent teeth; a mesially inclined incisor, for example, would often erupt with a midline diastema (*Figs.* 7D, 8).

Superimposition tracings of serial radiographs showed that the mesiodistal paths during incisor migration and eruption varied. Where the incisor was initially upright a straight path was followed, but where it was either mesially or distally inclined the eruption path was more curved

(*Fig*. 10). Though little movement of the incisor apex in this plane took place initially it did tend to migrate later. However, in some cases studied over a period where the incisor had been fully

Labiopalatal displacements and inclinations also improved spontaneously during migration (*Fig*. 11), but as the results of these were limited to subjective appraisal further investigation is

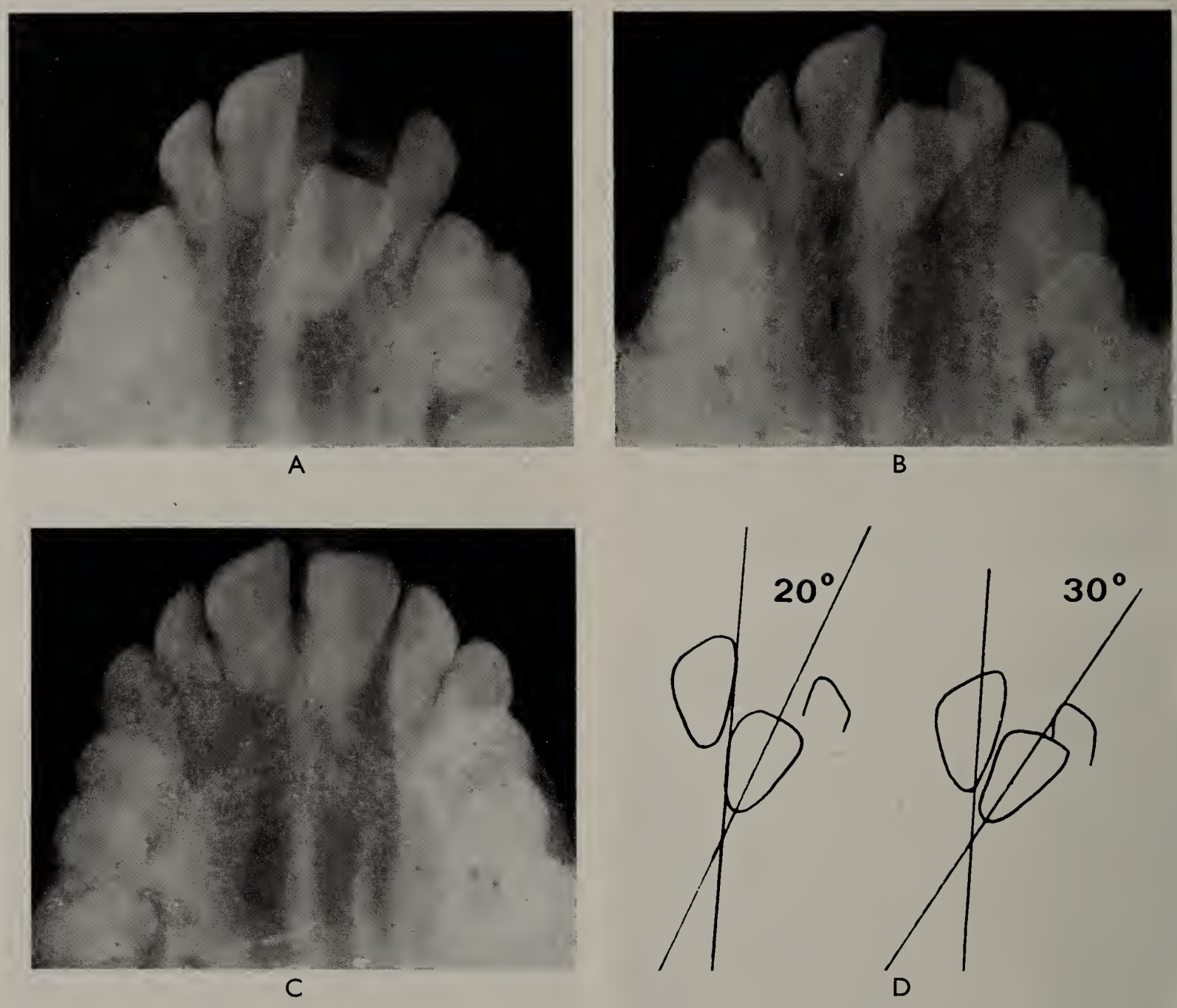


Fig. 9.—A boy with unerupted $\underline{|1}$. Occlusal radiographs: (A) at the age of 9 years 10 months, after removal of the supernumerary; (B) at 10 years 10 months, showing loss of eruption space and increase in the angulation of $\underline{|1}$; (C) at 13 years 2 months, showing eruption of $\underline{|1}$ following the creation of space. D, Tracings from (A) and (B).

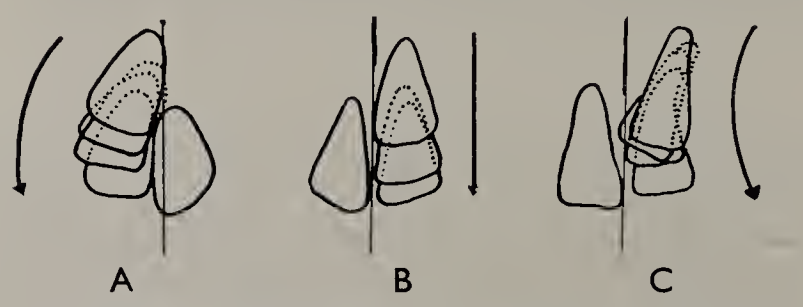


Fig. 10.—Superimposition tracings of incisor migration and eruption from serial occlusal radiographs. A, Distal inclination. B, Vertical. C, Mesial inclination.

erupted for 3 or 4 years, some displacement of the apex could often be detected (*Fig*. 6C). In certain instances this displacement appeared as an apical curvature when root formation was completed.

necessary. It does seem that spontaneous improvements in this plane are not so marked as in the mesiodistal plane. It remains to be seen how these findings may have a clinical application.

In all cases treatment was aimed at the creation of space and it is encouraging that nearly 75 per cent of the incisors erupted spontaneously. In 55 per cent of cases alinement was spontaneous and 34 per cent required some form of simple retraction. Fixed appliances were limited to rotations and apical displacements. Rarely was it found necessary to undertake vertical movement.

Any prediction on the eruption period after removal of a supernumerary is obviously an important aspect of treatment planning. It appears to rest mainly on two interdependent aspects of the malocclusion; the first is the type

and degree of displacement and the second is the space available to allow spontaneous movement of the type described above. If these factors can be controlled then incisor eruption should occur within a period of 1½ years. Obviously extremes of displacement can greatly increase this period.

Removal of the supernumerary when the incisor is unerupted is usually advocated in the mixed dentition at a time when premolars are still unerupted. In the majority of cases it is possible with simple appliances to create sufficient space at this stage by the removal of primary canines. In some cases, however, where more marked crowding is present the position of the unerupted permanent canine and premolars will prevent this and eruption fails to occur. It might be possible in such cases to delay the surgery, until the premolars could be removed. To substantiate this suggestion it was found that no significant difference existed in the eruption periods of the under-10 and the over-10 years age-groups. Furthermore, there was no statistical evidence that the degree of displacement of the incisor became worse in the older age-groups.

Finally, on the subject of surgical exposure of the incisor at the time when the supernumerary is removed: in the absence of sufficient space for eruption and a period to allow spontaneous migration it is felt hardly justifiable. Later when the incisor becomes lodged on the superficial soft tissues its simple exposure often hastens eruption without adverse effect on the gingival attachment.



A B

Fig. 11.—A boy with an unerupted $\underline{|1}$. A, Lateral radiograph at 10 years, showing labial displacement of $\underline{|1}$. B, Intra-oral photograph at 13½ years following spontaneous movement palatally of $\underline{|1}$ after the creation of space. (The crown of the incisor was exposed by a line incisor at 11½ years.)

SUMMARY

A method of investigating the relative effects of anatomical features on eruption has been described. The use of a large number of subjectively graded variables programmed through a computer enabled features associated with eruption to be determined and their relative effects on eruption to be analysed.

Complete or incomplete, curved or blunted roots, though found on the unerupted incisor, did not significantly effect the eruption period.

Displacements and inclinations which were associated with the unerupted incisor at a highly significant level had a more varied effect on the period of eruption. Whilst bodily displacement was the least significant, mesiodistal inclination and vertical displacement were the most significant features.

Though crowding in the dental arches was not significantly associated with the unerupted incisor the effects of space for eruption were paramount, not only on the period of eruption but also on the degree of spontaneous improvement.

A study of standardized occlusal radiographs indicated that in the presence of sufficient space spontaneous improvements of the incisor occurred during both migration and eruption. The most significant improvement was a change in the axial inclination which occurred initially about the apical third of the incisor root. The eruption path obtained in such cases was of a curved nature, with a relatively slower movement of the root apex to the erupting crown.

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CLASS II, DIVISION 2 INCISOR RELATIONSHIP: CAN IT BE AVOIDED?

A REPORT ON AN INTERCEPTIVE TREATMENT ILLUSTRATING ITS DEVELOPMENT AND SUBSEQUENT CORRECTION

G. H. STEEL, M.D.S. (Dunelm), F.D.S., D.Orth. R.C.S.

The Dental School, University of Newcastle upon Tyne

THIS report is based on photographs taken of the dentition of a child between the ages of 5 and $11\frac{1}{2}$ years. They illustrate the child's deciduous incisors, their exfoliation, and the eruption of the permanent incisors.

CASE REPORT

The patient, a boy of $8\frac{1}{2}$ years of age had a Class II, division 2 type incisor relationship (*Fig.* 1D) in that the upper incisors were displaced labially in relation to the central incisors which were in a virtually normal occlusion. At this stage of development the lateral incisors were only partially erupted, having not yet reached their fully displaced position and their incisal edges were as yet not lying outside the lower lip.

This patient had been seen $3\frac{1}{2}$ years previously at the age of 5 when he was observed to have a virtually normal occlusion of his deciduous incisors (*Fig.* 1A) with little or no spacing present between these teeth. One year later at age 6 years he had erupted his permanent lower central incisors, but still had no spacing between his deciduous upper incisors. By the age of 7 years (*Fig.* 1B) his permanent upper central incisors were erupted. One year later (*Fig.* 1C) his deciduous upper lateral incisors had exfoliated and the permanent lateral incisors could be observed to be lying quite superficially under the mucosa in a labially displaced position. A radiograph (*Fig.* 2) taken at this stage illustrates the relatively mild extent to which the laterals are short of space—in that they are overlapping the central incisors and the mesial curvature of the deciduous canines is encroaching on the lateral incisor space. Six months later the lateral incisors had erupted into the Class II, division 2 position as shown in *Fig.* 1D.

Realizing that the upper lateral incisors were displaced labially and were being deflected further labially by the closure of their spaces it was decided to extract the deciduous upper canines. As the incisal tips of the laterals were not yet lying outside the lower lip appliance therapy was considered unnecessary. Subsequently as the lateral incisors continued their active eruption they came to occupy a normal position inside the lower lip.

Two and a half years later the upper first premolars had erupted (*Fig.* 3). The lateral incisors were stable in a normal relationship, but the upper canines spaces were not adequate and the canines were placed buccally.

At this stage the upper first premolars were extracted and subsequently the canines commenced to erupt into a normal position.

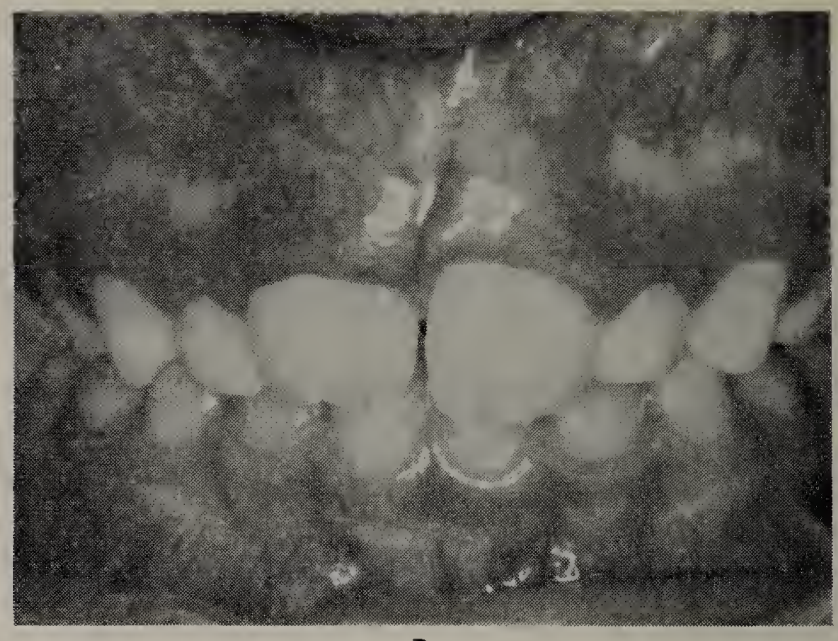
This case report illustrates the concept of occlusal care which has been described by various authors as serial extraction (Kjellgren, 1947), guidance of eruption (Hotz, 1947, 1970), and termed by others as 'developmental supervision'. It requires early recognition of a developing abnormality and its interception at the correct time. As applied to the case in this report a warning that the permanent dentition was likely to be crowded was present in the deciduous dentition when at the age of 5 years there was no spacing present between the deciduous incisors. This warning was more positive by the time the lower permanent centrals incisors had erupted, evidence that the permanent incisor teeth had commenced their eruptive phase. By the time the deciduous upper lateral incisors had exfoliated and the permanent upper lateral incisors commenced to erupt into a labially displaced position the abnormality was only too obvious. It was now time to intervene before the lateral incisors came to be deflected outside the lower lip, after which appliance therapy would be required to correct their position.

In Class II, division 2 cases the moulding action of the lips and tongue is usually favourable for alinement of the upper incisor teeth inside the lower lip. The milder examples such as that illustrated in this report respond well to interceptive care, the fully developed Class II, division 2 incisor relation being avoided. Is this not the ideal manner to care for such cases? If so, such

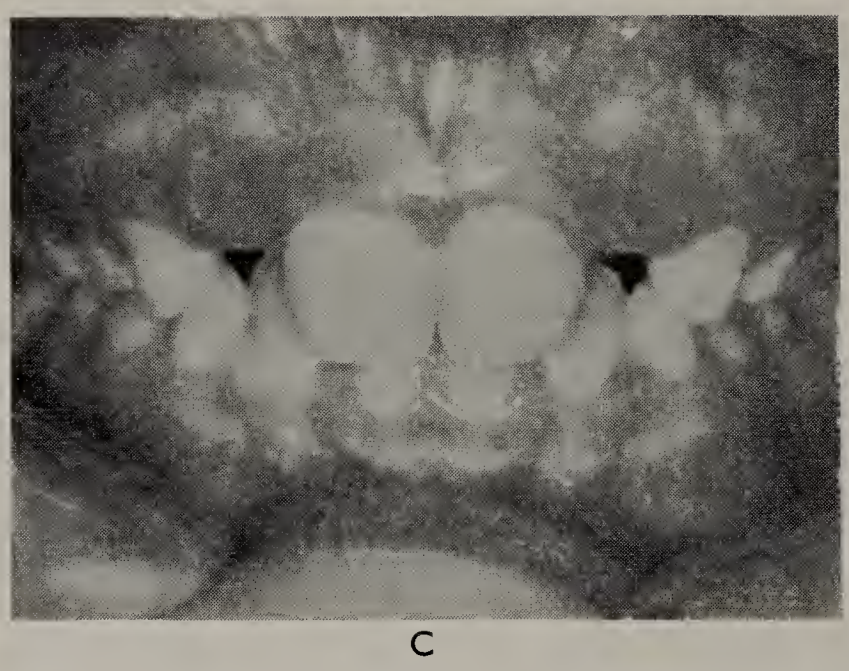
Presented at the meeting held on 11 January, 1971.



A



B



C



D

Fig. 1.—Serial photographs illustrating development of incisor relationship at ages 5, 7, 8, and $8\frac{1}{2}$ years.

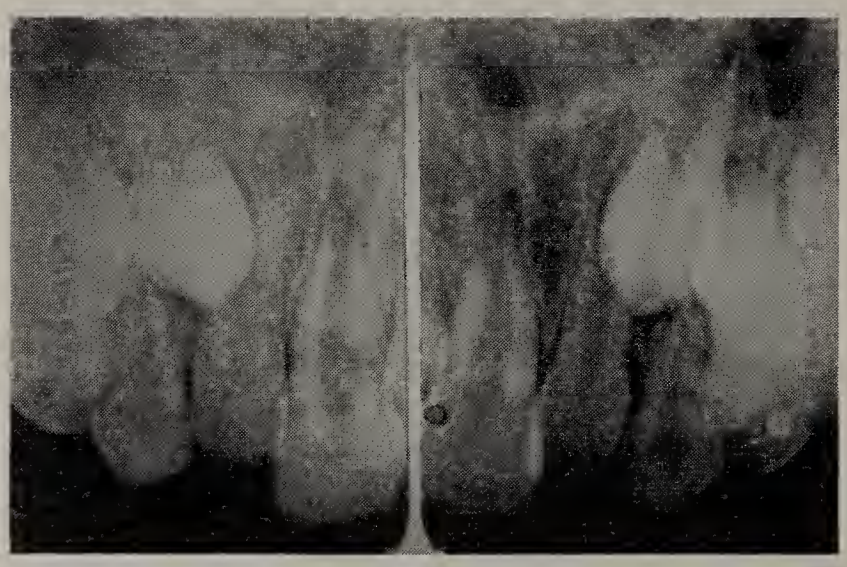


Fig. 2.—Radiograph taken at 8 years of age following exfoliation of B|B.

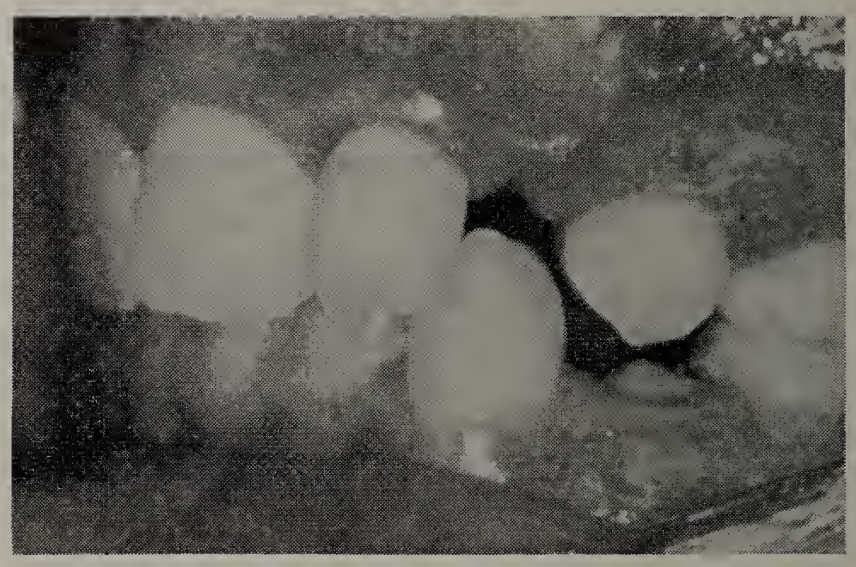


Fig. 3.—Incisor relationship at 11 years of age.

occlusal care is in the hands of the child's dentist. He is the person best placed to observe the child's developing dentition, to take heed of early warnings, and obtain the full advantage of interceptive care.

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USE OF SOME ADHESIVES IN ORTHODONTICS

J. J. CRABB, B.D.S., F.D.S., D.Orth. R.C.S.

H. J. WILSON, M.Sc. Tech., Ph.D., F.R.I.C.

The Dental School, University of Birmingham

MISPLACED unerupted teeth can present considerable problems in orthodontic treatment. The teeth most commonly involved are maxillary canines and one form of treatment is to expose them surgically and move them into their correct position by orthodontic appliances. It is always essential to obtain a firm attachment to the exposed tooth, and a variety of methods have been described to achieve this. A lassoo ligature was one of the earliest means. Hand-made bands, preformed bands, cast silver-alloy caps, inlays, and dentine screws are cemented to teeth complete with their attachments. The main disadvantages of these methods are their bulk, the difficulty of access in placing them and the problem of the fixed site of the attachment. Dentine screws and inlays also mutilate teeth and may be unsightly. A very useful adhesive, methyl cyanoacrylate, known as Eastman 910, has been available for some time and this has been used for instant cementation in many fields. It was, therefore, decided to consider this adhesive as a possibility for securing cast orthodontic attachments.

Fairly recently an ethyl cyanoacrylate, Permabond, has been introduced and one of its recommended uses is direct cementation of orthodontic brackets to enamel. Some concern, however, has been expressed in the literature regarding the possible toxic effects of both these cyanoacrylates. The butyl cyanoacrylate, Cyanodont, is considered by the manufacturers to be non-toxic and this adhesive was included in a short trial with the methyl and ethyl cyanoacrylates. It must be emphasized that the manufacturers have so far only recommended this material for protection of mucosa and wounds following oral surgery. In addition, the polycarboxylate cement Durelon was included in the trial. This cement, which was developed by Smith (1968), has been suggested for direct cementation of orthodontic brackets.

The aim of this research was to compare the effectiveness of these four materials in cementation of attachments direct to teeth. Tests were performed using extracted teeth in the laboratory.

EXPERIMENTAL

Materials

Three adhesives were chosen, all members of the cyanoacrylate group which are synthetic polymers (alkyl 2-cyanoacrylates). The forms were; butyl (Cyanodont), methyl (Eastman 910) and ethyl (Permabond, white tube—quick setting). They are low-viscosity liquids which polymerize when pressed into a thin film between two adherends. Polymerization takes place at room temperature without addition of a catalyst, and adhesion occurs within minutes. However, the Eastman 910 was supplied with a catalyst and this is claimed by the suppliers to produce a more uniform polymerization. The manufacturers of Permabond state that 'small amounts of moisture are needed to activate this reaction'. Both directions were followed in our experiments.

As a comparison, a carboxylate cement (Durelon) was also used, details of which are already well known. The liquid used was that recommended for cementation purposes.

Twenty-four maxillary canines extracted for orthodontic purposes were set in a standard block of clear acrylic resin reinforced by a wire driven through the root so that only the labial surfaces were exposed. Cast silver-alloy attachments were made to each tooth consisting of a circular disk 3 mm. in diameter with an eyelet included at right angles: their exact position on the tooth was known by cutting two vertical grooves in the side of the acrylic blocks and utilizing a jig constructed in two halves. The two halves fitted into each other and through the eyelet. The jig could then locate the attachment accurately on the tooth.

Method

The 24 teeth in their acrylic resin blocks were divided into 4 groups applicable to the 4 materials. The teeth and appropriate disks were scrubbed with pumice, washed with pure alcohol, and blown dry with compressed air. A small amount of each adhesive was placed on the disk, which was supported by the jig, and the disk pressed into position. Finger pressure was applied for 5

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minutes. For the cement, an exact ratio by weight of 2 parts of powder to 1 of liquid, was used. Temperature and humidity conditions were controlled at 21±1° C. and 50±10 per cent R.H. The bond strengths were assessed under dry conditions 15 minutes after cementation. The acrylic resin blocks were fixed in the lower jaws attached to the cross-head on an Instron testing machine. An attachment was fixed to the eyelet of the disk and also to the upper jaws, which in turn was connected to the load cell. A gradually increasing force was applied at 0·01 cm. per min. until the bond failed, this force being measured on a chart.

A second series of experiments was carried out on the same 24 teeth, this time using conditions similar to that which would occur in the mouth. The teeth and disks were cleaned with an excavator, pumice, pure alcohol, and blown dry again. The attachments were fixed, and 15 minutes later the assemblage was placed in *N* saline kept at 37° C. Twenty-four hours later the bond strengths were determined and results compared with those obtained under dry conditions.

RESULTS AND DISCUSSION

Summarizing results are shown in *Table I.* There is a wide range of results, which is to be expected when carrying out adhesion tests on small samples. The mean results for the adhesives indicate that the bond strength decreases considerably in wet conditions whereas the bond strength increased in the case of Durelon. The bond strength of Cyanodont, after the assemblage had been soaked in *N* saline for 24 hours, was very low, indicating that moisture affects the bond considerably. In view of the poor performance of the adhesive further long-term tests were considered unnecessary. Both Eastman 910 and Permabond showed similar results under wet conditions and since they are also considered toxic their use in orthodontics appears limited.

In the case of Durelon, wet strengths are higher because the material has aged and the setting reaction has gone further to completion. Long-term experiments, both in the laboratory and in the mouth, would be necessary for more complete results, but the work of Smith (1968) suggests these are satisfactory. However, his work with Misrahi (1969) was performed using stainless steel, which will produce a better bond than with silver. Clinical work has not always confirmed this view, perhaps because of the necessity to obtain an absolutely clean surface on the tooth and attachment, which is difficult clinically. A further paper by Misrahi and Smith (1971)

Table I.—Bond Strengths between Tooth and Silver Disk for Various Adhesives

Material	Condition	Range (*N*)	Mean (*N*)
Cyanodont (butyl)	Dry	52–81	68
	Wet	1–10	6
Durelon	Dry	11–21	16
	Wet	13–44	27
Eastman 910 (methyl)	Dry	18–92	50
	Wet	1–16	8
Permabond (ethyl)	Dry	16–70	45
	Wet	1–17	9

emphasizes this problem. It was noted that the bond failed between the silver disk and Durelon whereas in the case of the cyanoacrylates failure occurred between the adhesive and tooth.

If the bond strengths of the adhesives had been satisfactory it was intended to investigate them clinically, particularly on surgically exposed maxillary canines. Since the bond strengths deteriorated so rapidly under wet conditions, it is considered that the cyanoacrylates are not satisfactory under oral conditions.

Acknowledgements

The authors thank Professor T. D. Foster for his encouragement also Mr. P. Jones and Mr. D. Chinn for valuable technical assistance.

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THE TREATMENT OF CLASS II, DIVISION I MALOCCLUSION

P. H. MORSE, L.D.S., D.Orth. R.C.S. (Eng.), F.D.S. R.C.S. (Edin.)*

Senior Registrar, Eastman Dental Hospital, London

THE treatment of Class II, division 1 malocclusions has been exhaustively covered in the literature but I feel there are sufficient points of interest in the case to be described to justify its presentation and detailed description.

CASE REPORT

G.E., a boy aged 13 years, was referred by an experienced orthodontist because the fixed appliances felt to be necessary for treatment were not available at his practice (*Fig.* 1).

DIAGNOSIS

The patient has a moderate Class II skeletal pattern with a slightly reduced Frankfort-mandibular-plane angle and incompetent lips. The upper labial segment is markedly proclined and a little spaced. The lower labial segment is at a normal inclination and well alined. The overjet is increased to 13 mm., and the overbite is increased and complete to the palatal gingival margin of $\underline{21|12}$ (*Fig.* 2). The first molar relationship is a full unit Class II on the left (*Fig.* 2B) and essentially Class I on the right, $\overline{6}|$ having moved forward as a result of early loss. There is thus insufficient room for unerupted $\overline{5}|$ (*Fig.* 2C). The $\underline{E}|$ is retained and mobile; $\frac{6|6}{6|6}$ are filled, with buccal decalcification on $\underline{6|6}$ and lingual decalcificaion on $\overline{6|6}$. The $\underline{7}|$ is just showing through but $\frac{7}{|7}$ have not erupted. Radiographs confirm the presence of all the unerupted teeth developing, including the third molars. There may well be recurrent caries under the fillings in $\frac{6|6}{6\ 6}$ (*Fig.* 3A). There is apparently little bone labial to the upper incisor apices (*Fig.* 3B).



A B

Fig. 1.—Pre-treatment photographs with the lips at rest. A, Profile. B, Full face.

TREATMENT

Since $\frac{6|6}{6|6}$ are filled and carious and there is additional decalcification, these teeth have a poor long-term prognosis. Therefore it was decided to extract

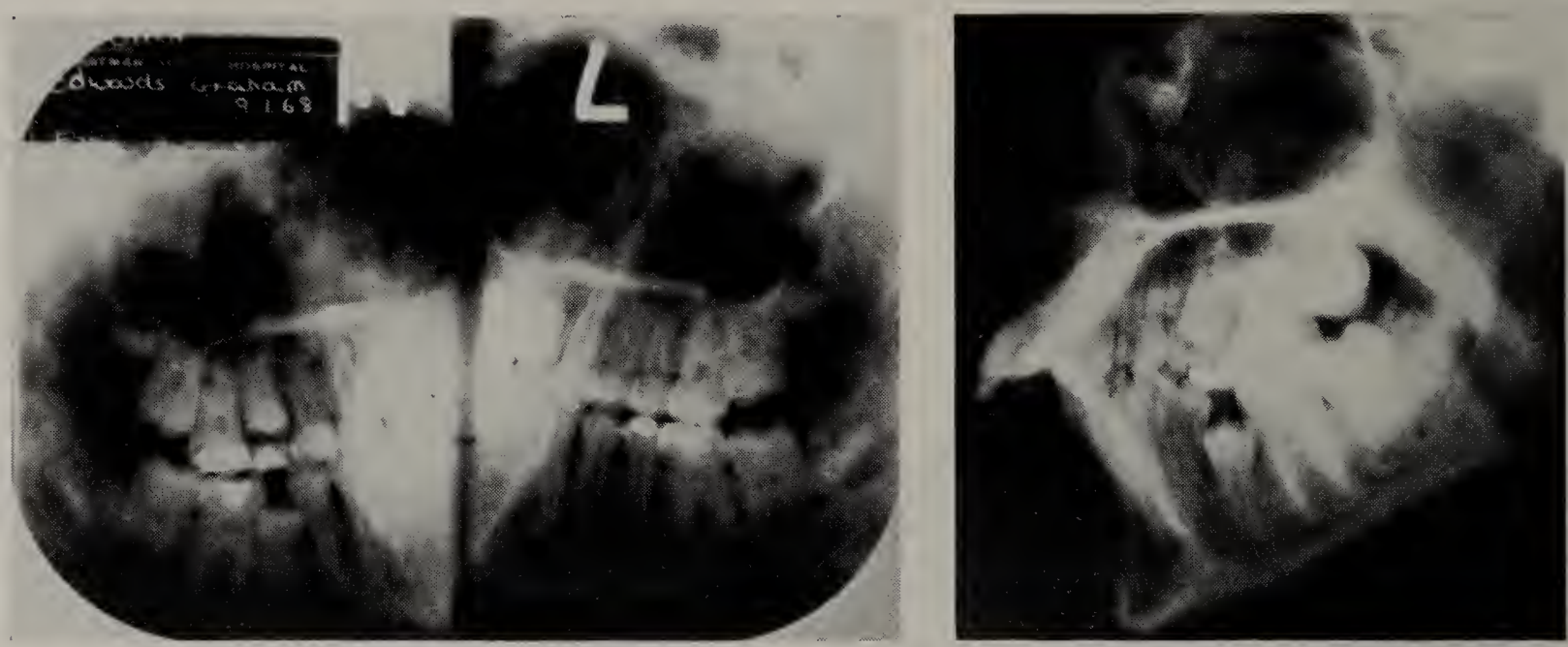
* Present address: Consultant Orthodontist, Orthodontic Unit, Booth Hall Children's Hospital, Manchester M9 2AA.

Presented at the meeting held on 11 January, 1971.



A B C

Fig. 2.—Pre-treatment study models. A, Anterior view from below to show the degrees of overjet and overbite. B, Left view. C, Right view.



A B

Fig. 3.—Pre-treatment radiographs. A, Half plate; note the recurrent caries in $\frac{6|6}{6|6}$. B, Lateral skull; note the lack of bone labial to the upper incisor apices.

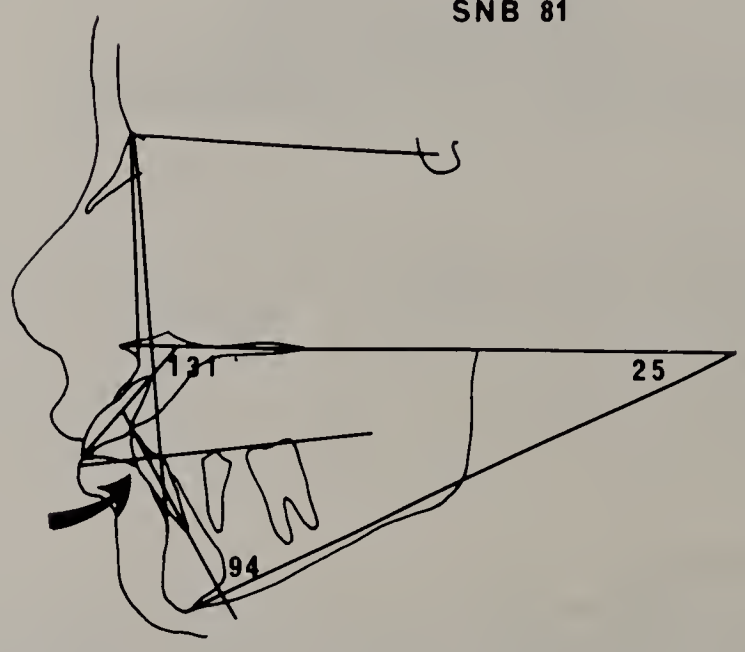


Fig. 4.—Tracing of the original lateral skull radiograph. Note the vertical part of lower lip is arrowed.



Fig. 5.—The upper removable appliance with cribs $\underline{51|15}$ and palatal canine retractors.

$\frac{6|6}{6|6}$ and to bring the patient back again in 3 months for extraction of $\underline{4|4}$ and appliance therapy (when $\underline{5}|$ should have erupted and $|\overline{7}$ should be erupting).

Three Months Later

Since $\underline{3}|$ shows some slight decalcification on its labial surface, initial treatment should consist of an upper removable appliance to retract $\underline{3|3}$, incorporating an anterior bite plane. A lower fixed appliance should then be used to bring forward $\overline{7|7}$ while depressing the lower labial segment and retracting it a shade, prior to overjet reduction. The depression and slight retraction of the lower labial segment was decided from the original lateral skull radiograph. The necessity for these manoeuvres is seen clearly from the tracing of the original lateral skull radiograph (*Fig.* 4). It is apparent that in order to retract the upper incisors so that they will be controlled by the second (vertical) part of the lower lip (Orton, 1966), it is necessary to depress and retract the lower labial segment.

August, 1969

The upper removable appliance was fitted to retract $\underline{3|3}$ with cribs $\underline{5|1|5}$ as shown (*Fig.* 5). The anterior bite plane was increased by cold-cure addition as treatment progressed.

October, 1969

The lower multiband appliance was fitted with Begg bracket attachments; an 0·45 mm. archwire with traction loops mesial to $\overline{3|3}$ was pinned in. Lower elastic intramaxillary traction (of 125 g. force) was instituted.

March, 1970

Upper arch: After 7 months' retraction $\underline{3|3}$ were sufficiently retracted. An impression was taken for the construction of a 1-mm. palatal arch with bands on $\underline{7|7}$ and 0·7-mm. stops to hold $\underline{3|3}$ in their retracted positions; the $\underline{7|7}$ bands were to have 0·9-mm. buccal tubes.

Lower arch: The $\overline{7|7}$ were well forward. An uprighting spring was inserted to derotate $\overline{5}|$.



Fig. 6.—Post-treatment photographs with the lips at rest. A, Profile. B, Full face.

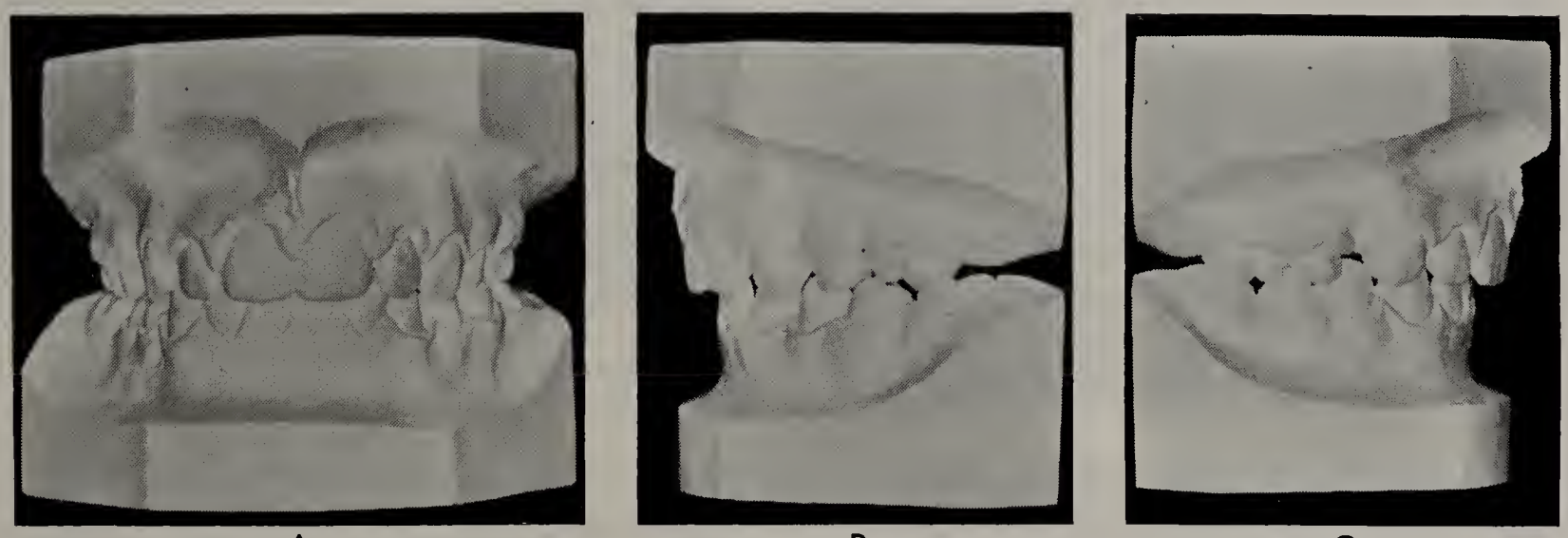


Fig. 7.—Post-treatment study models. A, Anterior view. B, Left view. C, Right view.

April, 1970

The palatal arch and bands $\underline{21|12}$ with Begg brackets were cemented. An 0·45 mm. archwire with traction loops distal to $\underline{2|2}$ was pinned to $\underline{21|12}$. Class II elastic traction of 50 g. was instituted to reduce the overjet. The overjet measured 15 mm. at this stage—an increase of 2 mm. from the original. This overjet increase probably resulted from the combination of lower labial segment retroclination and slight forward movement of the upper arch while retracting the upper canines.

May, 1970

The Class II elastic traction was increased to 75 g.

July, 1970

The Class II traction was discontinued, and instead upper intramaxillary traction (also of 75 g.) was instituted.

5 *August*, 1970

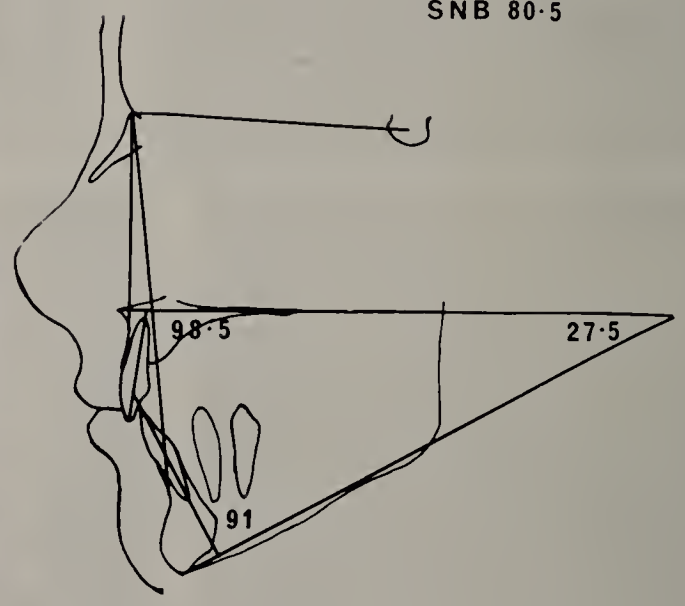
Uprighting springs were inserted to upright $\overline{5|3}\overline{3|5}$. The palatal arch was removed to allow $\underline{7|7}$ to move forward. Class III traction of 120 g. was instituted to oppose the reciprocal force of the uprighting springs and to move forward $\underline{7|7}$. The overjet was now 5 mm. (i.e., there had been 10 mm. reduction in 4 months).



A



B



C

Fig. 8.—Post-treatment radiographs. A, Half-plate; note $\frac{7|7}{7|7}$ forward in contact with $\frac{5|5}{5|5}$. There now appears to be sufficient room for the eruption of $\frac{8|8}{8|8}$. B, Lateral skull. C, Tracing of lateral skull radiograph.

28 *August*, 1970

The overjet was now 7 mm. (i.e., 2 mm. increase since 5 August). Almost certainly the lower labial segment had been retroclined by the Class III traction, and therefore this was discontinued. Only upper intramaxillary traction of 75 g. force was now used.

October, 1970

The overjet was now fully reduced (i.e., 6 months' treatment to reduce the overjet; 14 months' treatment

overall). Therefore the bands were removed and full records were taken (*Figs.* 6 ,7, 8). An upper removable retainer was fitted and the patient wore this for 2 weeks only. The lateral skull radiograph shows that the



Fig. 9.—Lateral skull radiograph taken following retraction of $\underline{3|3}$ and before overjet reduction. Note the depression of the lower incisors. Pointer on labial plate.

upper labial segment had been retracted well inside the lower lip activity (*Fig.* 8). The lower incisors were markedly depressed and retracted a little during the retraction of the upper canines (*Fig.* 9). The lateral skull radiograph taken at the time when the canines were fully retracted shows the pointer (previously described by Morse, 1969) on the labial plate. The original SN lower incisor tip angle was 87°; at the end of treatment it was 84·5°. The upper incisors have been retracted and their apices moved forward into ' space ', if the lateral skull radiographs taken at the beginning and end of treatment are superimposed. Incidentally, no resorption of the upper central incisor roots occurred during treatment, as seen from measurements of the pre- and post-treatment lateral skull radiographs, though a slight rounding of $\underline{|1}$ apex occurred (*Fig.* 10). The $\overline{7|7}$ have been moved forward into contact with $\overline{5|5}$ and there now seems to be sufficient space posteriorly for the eruption of $\frac{8|8}{8|8}$ (*Fig.* 8A).

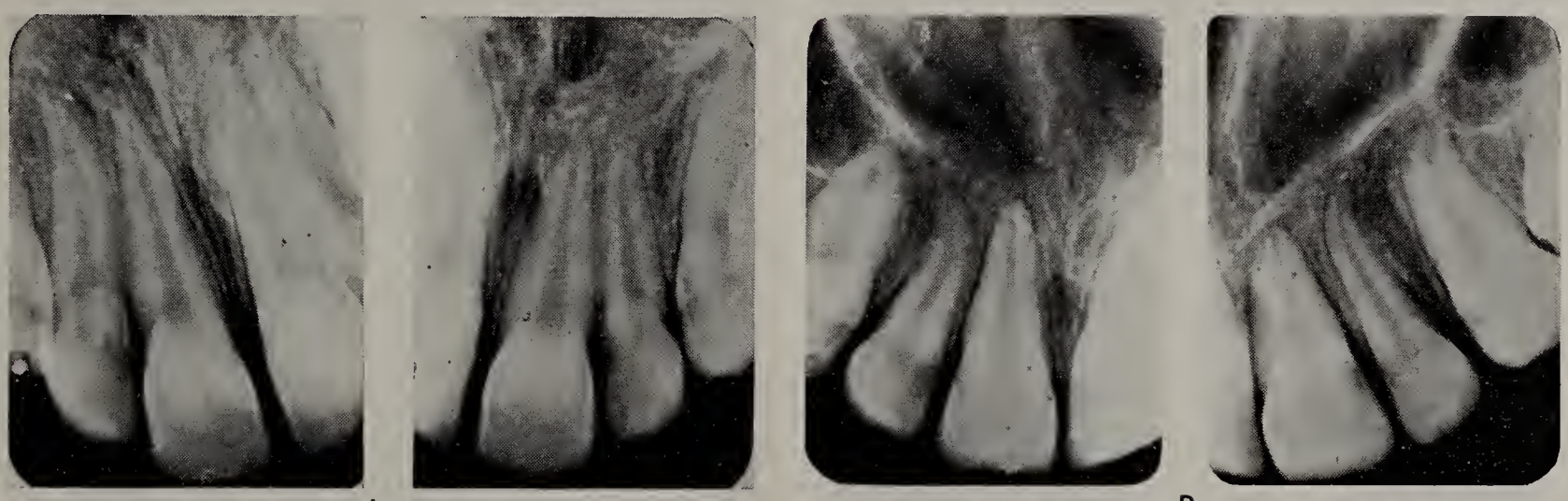
Summary of Treatment

1. The extraction of $\frac{64|64}{6\ |6}$.
2. An upper removable appliance to retract the canines, cribbing $\underline{5|5}$ thus allowing $\underline{7|7}$ to come forward as they erupt.
3. A lower multiband to depress and retract the lower incisors while bringing forward $\overline{7|7}$ with elastic traction.
4. A palatal arch to hold $\underline{3|3}$, banding $\underline{7|7}$. Bands on $\underline{21|12}$, 0·45 mm. archwire with latex elastic Class II traction, and subsequently upper intra-traction to reduce the overjet. Class III traction for a short while to counter any proclining force during the uprighting of lower posterior teeth.

DISCUSSION

This case is of interest because of the following features:—

1. A deep overbite originally. The overjet was very increased, and to reduce this, it was important to reduce the overbite (Ballard, 1967).
2. Little labial bone was apparently available into which the upper incisor roots could be moved during overjet reduction.



A B

Fig. 10.—Intra-oral radiographs of the upper incisors. A, Before treatment. B, After treatment. Note slight ' rounding ' of $\underline{|1}$ apex.

3. The first molars were heavily filled and also decalcified and carried poor long-term prognoses.
4. Speedy reduction of the overjet occurred and the overall treatment was short.
5. There was good control of the mesial movement of $\overline{7|7}$ with a single arch in a round tube. The $\underline{3|3}$ were not particularly tilted during their retraction with the upper removable appliance.

The extraction of the upper first molars give a reduction of buccal segment crowding but anchorage is difficult to maintain, especially while retraction of the upper premolars and canines is being carried out prior to overjet reduction—extraction of $\frac{6|6}{6|6}$ doubles the treatment time and halves the prognosis (Mills, 1964).

Since there was crowding in the lower premolar regions and also some lower first molar space would be taken up in providing anchorage for retraction and depression of the lower incisors, little extra anchorage was available in the lower arch for overjet reduction. Therefore, the extraction of $\underline{4|4}$ in addition not only reduced the overall treatment time but also ensured a good prognosis for overjet reduction. Following extraction of $\underline{4|4}$, additional upper arch anchorage was available if Class III traction was felt to be necessary to prevent proclination of the lower incisors. There was also less chance of subsequent relapse from forward pressure of the erupting $\underline{7|7}$ or $\underline{8|8}$.

In general terms, if $\frac{6|6}{6|6}$ have to be extracted, then one may wait for a long time for $\underline{7|7}$ to erupt before commencing treatment. Personally, I have waited until a patient was 15 years old for $\underline{7|7}$ to erupt sufficiently to be held back, and only then could retraction of upper premolars and canines be commenced.

The extraction of $\overline{6|6}$ usually produces enough lower arch anchorage, but the tendency for forward movement of $\underline{7|7}$ following loss of $\underline{6|6}$ is so great that additional anchorage support (e.g., extra-oral) is frequently necessary in all but the simplest malocclusions. Therefore, in Class II, division 1 malocclusions with a *severe* overjet increase and poor quality $\frac{6|6}{6|6}$, the extraction of $\underline{4|4}$ in addition to $\frac{6|6}{6|6}$ is suggested.

As a variation of this, if the extraction of first molars is carried out at the ideal time, then it is possible to reduce the overbite and partially reduce the overjet with an Andresen appliance. The $\overline{7|7}$ should then erupt close to $\overline{5|5}$ and active lower arch treatment may not be necessary. The $\underline{4|4}$ may be extracted later to allow $\underline{3|3}$ to drop back and the final overjet reduction will allow treatment of a difficult malocclusion to be finished by the age of 11 years.

Acknowledgements

I wish to thank Professor Ballard for permission to publish details of this case which was under his care. I am grateful to the Photographic Department of the Eastman Dental Hospital for preparing the illustrations, to Mr. Titshall for preparing the models, and to Miss J. Jeffrey for secretarial assistance.

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MALOCCLUSION ASSOCIATED WITH AN EXTENSIVE LYMPHANGIOMA OF THE FACE

C. C. KNOWLES, B.D.S., M.D.S., D.D.O.
Consultant Orthodontist, Alder Hey Children's Hospital, Liverpool

THE purpose in presenting this case is to illustrate how a combined treatment plan can be worked out and executed by the specialities who are interested in it—in this case, plastic surgeons and orthodontists.

CASE REPORT

The child's hospital career began some ten years ago when she was 3 years' old and admitted to hospital suffering from respiratory distress due to pressure upon the trachea of an extensive lymphangiomatous infiltration of the neck. A tracheostomy was performed but no reference was made in the notes of any other affected area, but the chin, floor of the mouth, and tongue must have been involved at this time.

She had repeated surgery to re-establish the tracheostomy until she was eventually left with a permanent tracheostomy opening at the age of 6. By this time the tongue was causing embarrassment because of its size, and a partial glossectomy was performed when the anterior third of the tongue was removed. When an attempt was made to close the mouth at the end of the operation it was noted that the incisors failed to meet and this seems to be the first reference to the presence of an anterior open bite. The paediatric surgeon then requested an orthodontic opinion and the child was kept under observation by a colleague until her permanent incisors had erupted.



Fig. 1.—Frontal and lateral views of the face when seen in 1966. The scars of previous surgery can be seen and also the permanent tracheostomy.

Presented at the Country Meeting. held on Thursday, 22 April, 1971.

I first saw the girl in 1966 when she was referred for the assessment of her malocclusion in so far as it was associated with her general facial deformity, caused by the lymphangioma in which the plastic surgeons were interested (*Fig.* 1).

The Malocclusion

Clinical examination revealed an anterior open bite in association with a large maxilla-mandibular (MM) angle, but the inclination of the upper and lower incisors did not appear to be outside normal limits. These teeth were discoloured and poorly calcified.

The tongue did not appear excessively large but, of course, the actual amount previously removed could not be ascertained. It was infiltrated with lymphangiomatous tissue and could be best described as 'stiff'. The mobility was limited and its shape remained constantly thick from dorsal to ventral. Speech was rendered indistinct by a combination of tongue immobility and the anterior open bite.

Cephalometric examination in 1966 showed the following readings (*Fig.* 2); ANB, —4°; SNA, 77°; MM, 42°; Upper incisor angle, 112°; Lower incisor angle 90°.

Note also the bony irregularities around the chin region.

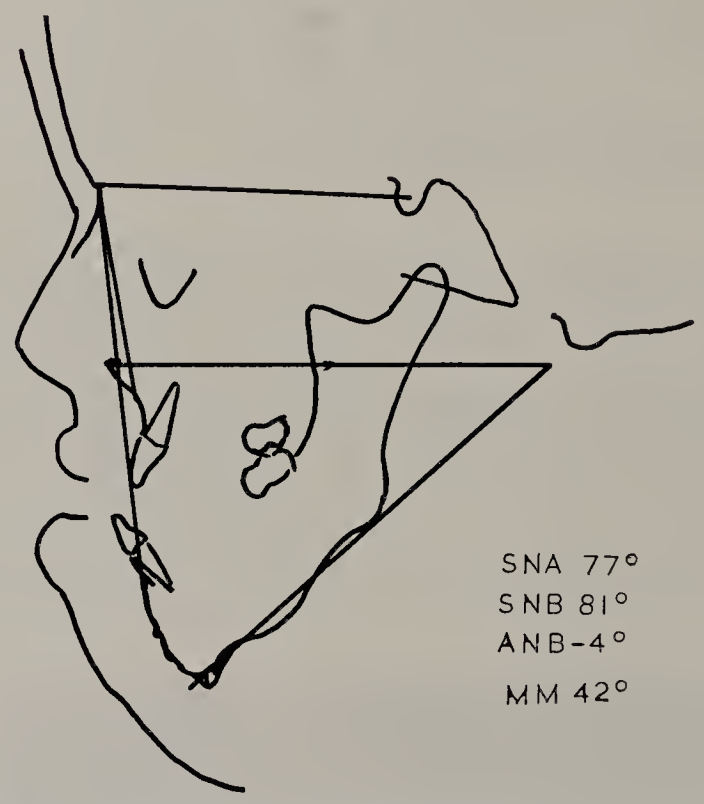


Fig. 2.—Tracing from cephalometric X-ray in 1966. Note the irregularities on the front and underside of the chin.

Treatment Plan

The referral of the child for an orthodontic opinion was for obvious reasons since there would be no point in reducing the excessive subcutaneous tissue of the chin alone because the underlying distortion of the mandible was the cause of considerable facial deformity in its own right. Therefore, a combined operation was planned in such a way as to establish both normal incisor occlusion and a reduction of the bulk of the tissue covering the chin. In addition, it was planned to smooth off some of the bony excrescences on the front of the mandible.

An ostectomy of the body of the mandible was worked out in a standard manner from study models and the lateral headplate and a template constructed for each side to indicate the amount of bone to be removed (Knowles, 1967). The premolar region was a convenient one for this procedure since one of the second premolars was congenitally absent (*Fig.* 3). Note that the MM angle has increased since 1966 (*Fig.* 2). This may be due to further deposition of bone under the chin. There has also been a relative increase in angle SNA resulting in a reduction of the negative value of angle ANB.

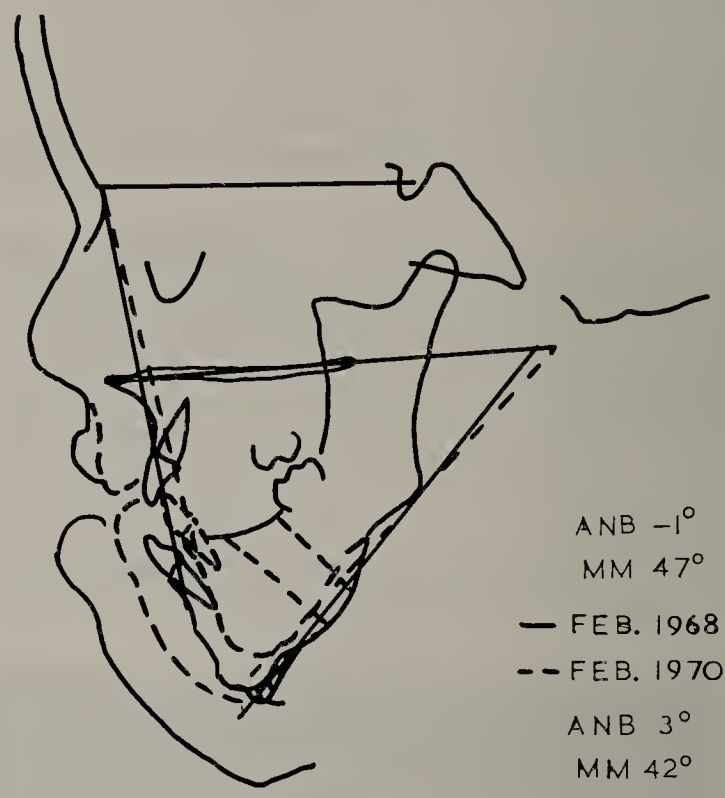


Fig. 3.—Preoperative and 2 years postoperative tracings. The area between the two vertical broken lines on the body of the mandible indicates the amount of bone removed at the time of the ostectomy. Note the change in soft tissue profile between the preoperative continuous outline, and postoperative condition, broken outline.

Surgical approach to the body of the mandible was through the scars of previous surgery and this approach also allowed access for the removal of the thickened subcutaneous tissue. The bony protuberances on the surface of the mandible were smoothed off with an acrylic trimming bur. Repeated repositioning of the flap enabled us to judge the progress made in the reduction of the bulk of the soft tissue overlying the chin.

Fixation was by means of conventional cap splints, with circumferential wires and prefabricated connecting bars. Provision was made for intermaxillary fixation but use was not made of it in the first 48 postoperative hours and after this, the stability in the mandible seemed sufficiently firm to enable us to leave the mandible free to move.

Postoperative Evaluation

Good bony union was achieved in 6 weeks and this was easily tested clinically by removing the connecting bars temporarily. It took a considerably longer time for the postoperative oedema to subside, but eventually it did. Antibiotic cover was provided for 3 weeks postoperatively.

A tracing of a headplate taken 2 years later shows a good incisor relationship and a reduction of the MM angle by 5°. The change in the outline of the soft tissues can also be seen (*Figs.* 3, 4).

The child still has a legacy of scarring, the lower lip is a little immobile, but speech is very much improved although this is only a subjective assessment.





Fig. 4.—The appearance and occlusion in 1970.

The greatest change for the better is to be noticed in the child's outlook on life. She is now accepted by her school-fellows as a reasonably normal girl and has been happily adopted into the family of relatives, having previously been rejected by her own parents.

DISCUSSION

The gross deformity of anterior open bite and mandibular prognathism found in the case reported may have been associated with the pathologically enlarged tongue, presumably present from birth. This type of deformity is seen in cases of isolated tongue enlargement without the involvement of other regions of the face as found in this case.

The abnormal bony deposits on the outer surface of the mandible can be related to the presence of the investment of lymphangiomatous tissue and a possibly over-generous supply of nutrition to the region.

Although there was an increase in the MM angle over a period of 2 years prior to surgery, the lack of postoperative relapse in a corresponding length of time would hopefully indicate that the anterior open bite was not a relapsing condition. The increase in the MM angle would be associated with the local increase in the bony growth around the chin. The immobility of the tongue will make it unlikely that this organ will produce any recurrence of the anterior open bite.



SUMMARY

An example of a severe facial deformity is shown to illustrate how the greatest good can be achieved when the specialities concerned in the treatment, in this case plastic surgery and orthodontics, enjoy the degree of mutual co-operation that we are happy to possess.

Acknowledgements

In this instance I am grateful to Mr. A. H. M. Littlewood, Consultant Plastic Surgeon, who

referred the child to me for the occlusal assessment and planning of the ostectomy and in this way making our combined operation produce such a satisfactory end result.

I am also indebted to Mr. A. E. Orritt, Maxillofacial Technician, Alder Hey Children's Hospital, for his skill in splint construction; and to Mr. M. Bayliss, Medical Photographer, Whiston Hospital, for the black and white illustrations taken from colour transparencies.

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MULTIPLE-STRAND ARCHES

C. D. STEPHENS, B.D.S., F.D.S., D.Orth.

W. J. B. HOUSTON, B.D.S., F.D.S., D.Orth.

N. E. WATERS, M.Sc., Ph.D., F.Inst.P.

Royal Dental Hospital of London, School of Dental Surgery

THE consensus of opinion in the current orthodontic literature is that light forces should be used for moving teeth. This has led to a search for fixed-appliance archwires which are sufficiently flexible to apply light forces even when deformed to a considerable extent by tying in. Johnson (1934) pointed out that by using two thin wires in place of a single thicker one a more flexible arch can be obtained.

Multiple-strand arches using the same principle as the twin-wire arch have recently been produced commercially. Several of these archwires (*Table I*) have been tested, both clinically and in the laboratory, and have been compared with other types of fixed-appliance archwire.

but that the multiple-strand arch can be deflected further without permanent deformation.

Multiple-strand arches are graded by their external diameters, although the cross-sectional area of the wire will be less than that of a single-strand wire of the same nominal external diameter (*Fig.* 2). Thus, a multiple-strand arch of nominal diameter 0·45 mm. (0·018 in.) may be considered to be equivalent to a single strand of only 0·3 mm. (0·012 in.) in terms of its load–deflection properties. It is evident that because it contains less wire a multiple-strand arch of nominal 0·45 mm. diameter will apply very much lighter forces than a single strand arch of 0·45 mm. diameter when deflected by the same

Table I.—DETAILS OF THE ARCHWIRES WHICH WERE TESTED

PRODUCT	MATERIAL	FORM	MANUFACTURER
0·45-mm. (0·018-in.) Orthoflex superspring	Heat-treated, high tensile, stainless-steel	3×0·04-mm. strands, tightly twisted, 16 turns per inch	Dentaurum
0·45-mm. (0·018-in.) Orthoflex extraspring	High tensile stainless-steel		
0·45-mm. (0·018-in.) Twistflex	High tensile stainless-steel	3×0·04-mm. strands, 5 turns per inch	Unitek
0·45-mm. (0·018-in.) Bundle arch	Elgiloy 'Red' / Elgiloy 'Green'	4 strands laid parallel	Rocky Mountain
Twin-wire arch	Hard stainless-steel	2 strands, 0·25 mm., laid parallel	—

LABORATORY INVESTIGATION

The effect of using a number of thin strands in place of a single archwire of the same material and cross-sectional area is to increase the elastic deformability while leaving the slope of the load–deflection curve unaltered (*Fig.* 1). This means that both archwire types will be deflected through a similar distance by a given light load amount. However, the multiple-strand arch can be deflected through a much greater distance without becoming permanently deformed.

Some multiple-strand arches (e.g., twin-wire arch, Bundle arch) have their strands laid parallel, while others (e.g., Twistflex and Orthoflex) have strands twisted around one another (*Table I*). This twisting seems to have no appreciable effect on the physical properties of the

From a Table Demonstration presented at the Country Meeting held on 23 April, 1971.

archwire, although it may offer clinical advantages.

A variety of laboratory tests was performed on all the types of multiple-strand archwires.

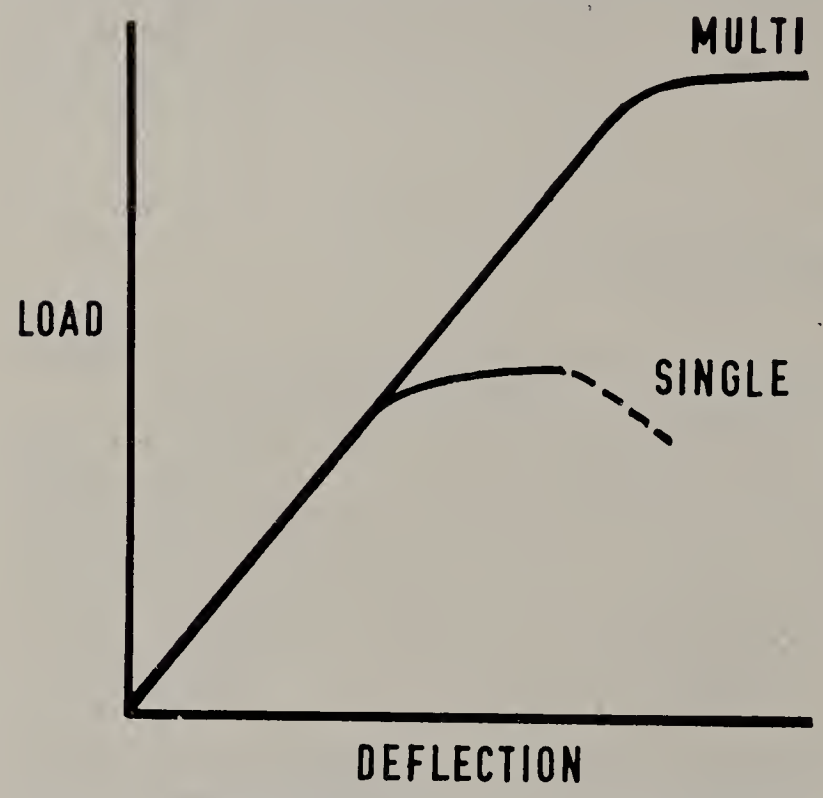


Fig. 1.—Load-deflection curve of comparable single- and multiple-strand arches.

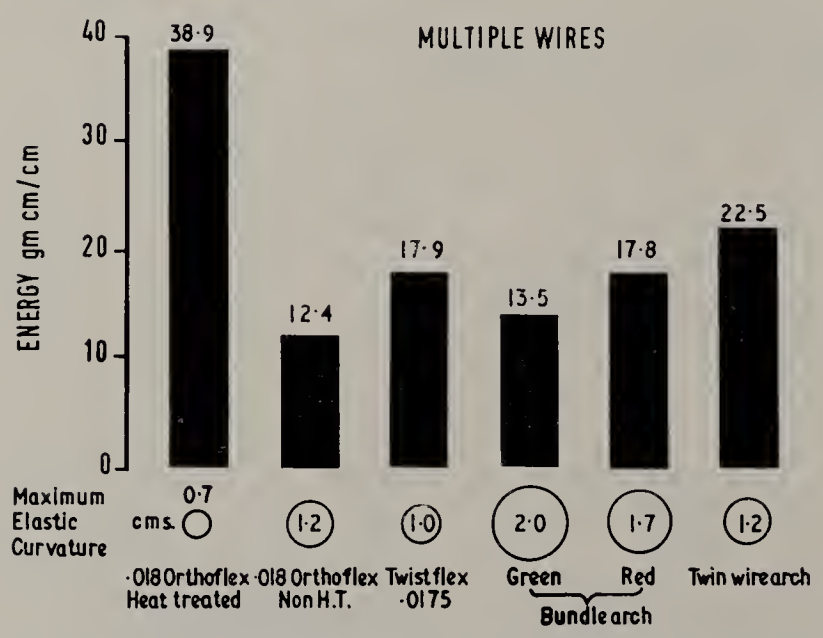


Fig. 3.—The elastic energy characteristics of the wires which were tested.

Since load–deflection curves are meaningful only when comparing similar wires, tests of more direct relevance were devised (Stephens and Waters, 1971). These involved measuring the minimum radius from which there was complete elastic recovery (depicted by the size of circle in *Fig.* 3), and calculating the energy stored per unit length of wire at this stress (indicated by the height of column in *Fig.* 3). As a general guide the wires with the smallest circles and the highest columns are those with the most useful clinical properties, since these provide the greatest useable energy over the widest range.

LABORATORY FINDINGS

Multiple-strand arches are available in a variety of sizes; 0·45-mm. (0·018-in.) wire was chosen as being the size most frequently used in the orthodontic department of the Royal Dental Hospital. Of the samples tested, Orthoflex superspring hard had the greatest elastic range by a considerable margin (*Fig.* 3). This wire is heat-treated and its properties are very much better than those of the Orthoflex extraspring hard, which is not heat-treated. Compared with a conventional twin-wire arch made from two 0·25-mm. (0·01-in.) strands of hard stainless-steel wire (K. C. Smith) the heat-treated Orthoflex had approximately twice the elastic range and could store twice the energy. The Bundle arches (Elgiloy) had less elastic deformability than the conventional twin-wire arch and had comparably reduced energy levels. The Twistflex fared only slightly better, coming second in order of elastic range (*Fig.* 3).

Fig. 2.—The reduced cross-sectional area of a multiple-strand arch compared with a solid wire of the same overall diameter.

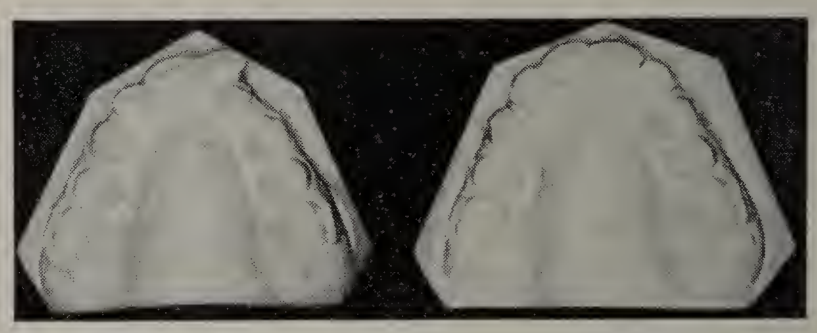


Fig. 4.—The initial alinement produced by one 0·45-mm. stranded archwire over a period of 3 months.

COMPARISON WITH MULTI-LOOPED ARCHES

When used to aline markedly irregular teeth the conventional single-strand round-wire arch

may have vertical loops incorporated to increase its flexibility. It was found that when measuring flexibility across a single tooth span, a wire such as 0·4-mm. (0·016-in.) T.P. orange super plus had to have vertical loops at least 7 mm. long in order to be as flexible as the 0·45-mm. Orthoflex superspring hard arch. Loops of this length may be impracticable in many clinical situations and this degree of flexibility is achieved only in the horizontal plane.

CLINICAL FINDINGS

The twisted arches were found to be more convenient clinically than the parallel-laid arches. Of the twisted arches, Twistflex is available in a variety of lengths with soldered ends to prevent fraying, but if it is necessary to cut the wire to a suitable length the ends do become separated. The Orthoflex wires are twisted in such a way that they do not readily become unravelled and the ends do not need to be soldered. It is also possible to incorporate satisfactory traction loops in this type of wire.

The better multiple-strand archwires find an immediate application in replacing the twin-wire section of the Johnson arch (*Fig.* 4). Although the usual buccal sheath can be used to support the arch, this is not essential as the arch is so flexible that it is not usually distorted by the patient.

The multiple-strand arch is particularly suitable for initial alinement with any type of bracket. Intramaxillary traction can be applied to loops in the canine region, but intermaxillary traction should not be applied to these arches as they are not rigid enough to counteract the buccolingual forces which are introduced by this procedure. It is not possible to use anchorage bends since the arch flexibility allows rolling in the buccal tubes and this produces uncontrollable molar movements. In the type of case where space is critical and anchorage bends are essential from the outset, it is safer to use the conventional multi-looped type of arch. However, with care, loss of anchorage is not usually a problem during initial alinement with these arches, as only very light intramaxillary forces are required.

In handling the arch it is inadvisable to ' wipe in ' an arch-form, as it is difficult to avoid introducing a spiral curvature. Arch-forming should be confined to contouring around the canines by adjustment at the traction loops. The extreme flexibility makes turning down the ends of a multiple-strand arch difficult unless they are annealed or unless fine pliers are used.

ADVANTAGES OF MULTIPLE-STRAND ARCHES

1. Minimal chairside time.
2. Minimal oral hygiene problems.
3. Rapid alinement.
4. It is impossible to apply heavy forces.
5. Equal flexibility in all planes.
6. Very resistant to damage.

DISADVANTAGES OF MULTIPLE-STRAND ARCHES

1. Over-rotation can only be achieved by the same means as used in twin-wire arch technique, i.e., Mills tubes or offsetting brackets.
2. Anchor-bends and toe-in cannot be used for the reasons stated.
3. Intermaxillary traction is difficult to apply.

CONCLUSIONS

1. Multiple-strand arches offer considerable advantages as initial alining arches with any type of bracket because of their flexibility in all planes.
2. Stranded archwire should supersede the use of hard stainless steel in the anterior section of the twin-wire arch.
3. Of the archwires tested, Orthoflex superspring hard demonstrated superior clinical and laboratory properties.

Acknowledgements

We would like to thank Miss J. Middleton for the illustrations and Miss H. Lander for secretarial help.

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AN INTERIM REPORT ON AN ELECTROCHEMICAL METHOD OF INVESTIGATING STAINLESS-STEEL ORTHODONTIC WIRES

D. W. WILLIAMS, B.D.S., F.D.S., D.Orth. R.C.S.

J. A. VON FRAUNHOFER, M.Sc., Ph.D., A.R.I.C., A.I.M.

Institute of Dental Surgery, Eastman Dental Hospital, London

INTRODUCTION

STAINLESS-STEEL wires are generally expensive, and yet their quality is not always within clinically acceptable limits, even if one takes into account the practical difficulties of manufacture. The clinical performance of an orthodontic wire is strongly dependent upon its manufacturing process, clinical manipulation, and heat treatment. However, apparently standard techniques often produce erratic clinical performances. The reason for this is that the critical relationship between the composition, structure, and the correlated physical properties are not at present clear. This is understandable, for the relationship is not only complex but is extremely difficult to investigate.

In orthodontic practice, the main types of wire used are:—

Soft drawn, which is used for hooks, stops, and ligatures for tying in archwires. When examined microscopically, this can be shown to exhibit the classic although perhaps slightly distorted structure of Austenite, with the suggestion that other phases are present (*Fig.* 3A).

The British standard for orthodontic stainless-steel wires indeed suggests that 18:8 austenitic wire should be used for orthodontics.

Hard drawn wires are used for cribs, springs, and labial bows, and have been work hardened to a greater extent in the drawing process. When this is viewed microscopically, the structure is more compacted, and much less easily recognizable as Austenite or any other discrete phase.

Extra-hard drawn wire is used in multiband techniques, and has received the greatest degree of work hardening in its drawing process. Its microstructure is the most complex, being utterly distorted. If the wire is examined microscopically, it is difficult to distinguish any discrete phases by a simple etching procedure. After manipulation, rather empirical heat treatment procedures are often attempted which add further complexities to the structure.

It is probably these changes in structure which result in the success or failure of the wires in clinical use.

It is felt that it is necessary to characterize the discrete phases in the wires. If the microstructure can be correlated with the composition and physical properties, it should then be possible to evaluate which wires will best fulfil a clinician's requirements. It should also be possible to suggest the best combination of manipulation and heat treatment. The critical factor of this ideal is to be able to recognize the discrete phases in the microstructure, and this in turn is dependant on the process of etching.

ETCHING

Etching is the selective predominant dissolution of one phase of those present in the metal structure. The result is that the surface is thrown into relief, and shadows are then resolvable when viewed under reflected light. Various solutions are used as etchants, e.g., acidic solutions such as ferric chloride, and redox solutions such as chromic acid. They may be water or alcohol based. Alternatively, the specimen can be electrolytically etched in, for example, 10 per cent oxalic acid.

Both of these relatively simple methods, however, require considerable experience and skill to be able to predominantly etch out one specific phase and are not easily applied to complex structures. Appreciating the complexity of the

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microstructure of the extra-hard drawn wires, a more sophisticated method of etching is necessary and a device known as a potentiostat was used to this end (von Fraunhofer and Banks, 1972).

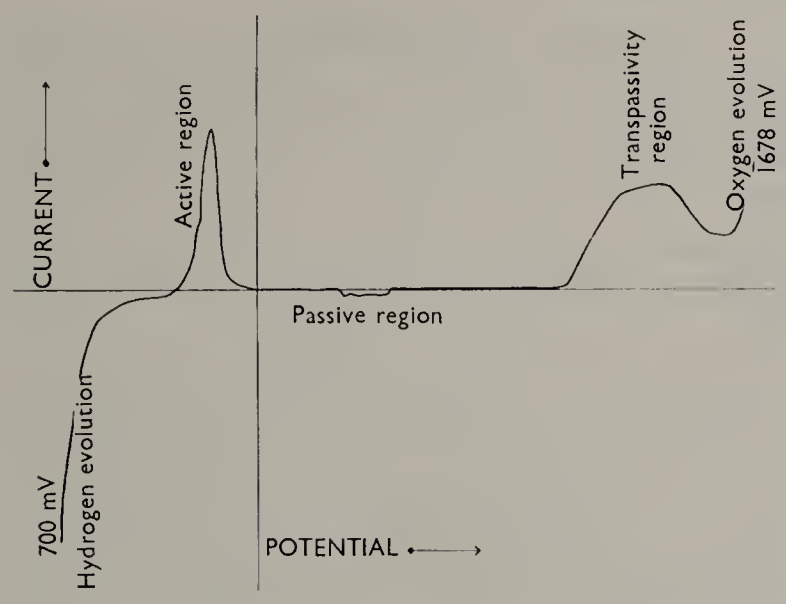


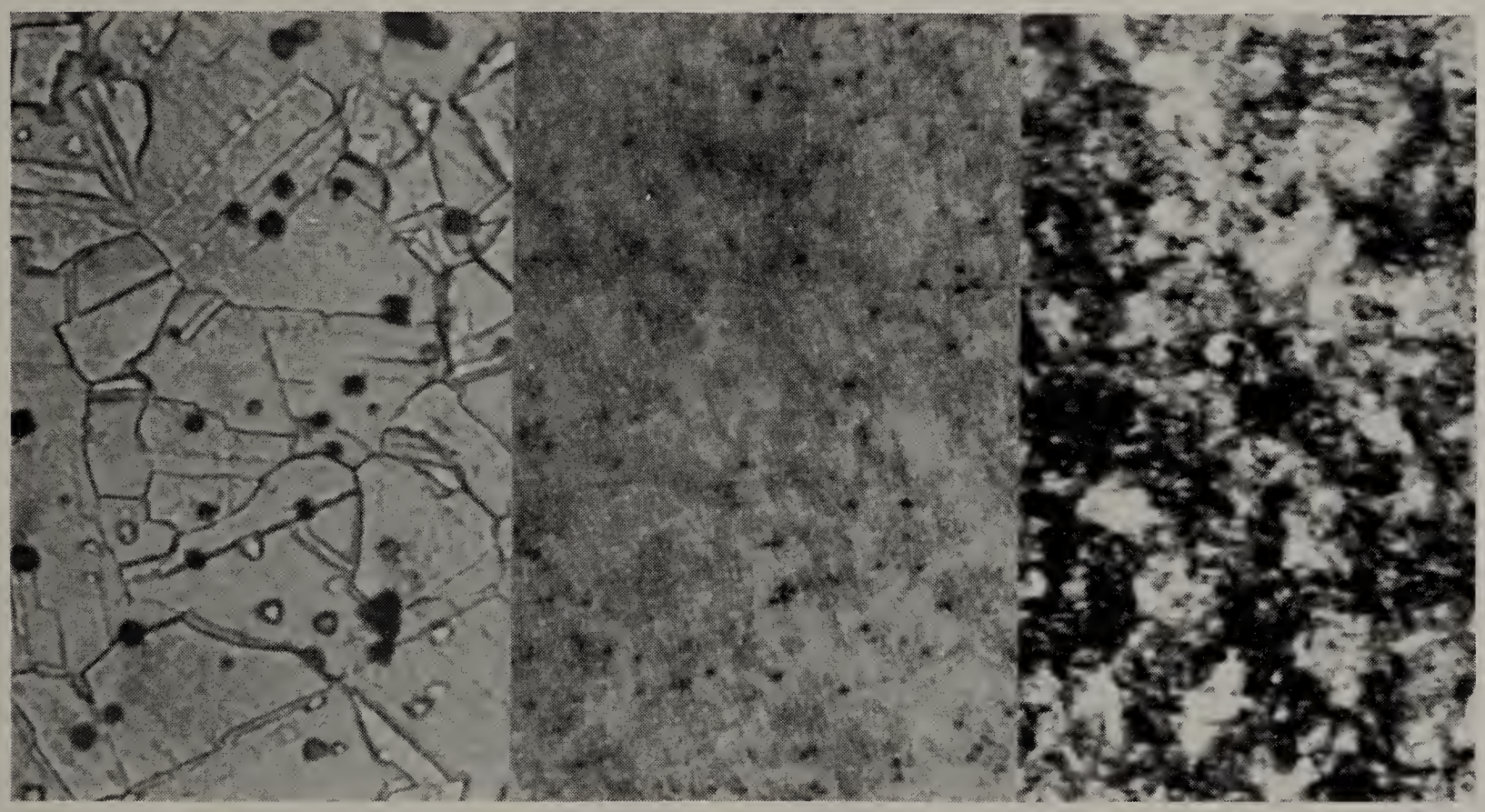
Fig. 1.—A potential/current curve, showing the typical features of a potential sweep.

The potentiostat determines the potential of the wire by comparison with the standard calomel electrode, and if it varies from that which the operator preselects, the potentiostat maintains the set potential by passing a current between the auxiliary platinum electrode and the wire.

The electrochemistry and electronics involved exceeds the scope of this paper, but it is sufficient to state that selective dissolution or etching, of



Fig. 2.—Transverse and longitudinal section specimens mounted with electrical connexions in acrylic.



A B C

Fig. 3.—Transverse sections of wires potentiostatically etched, at a magnification of 2100 times under oil-immersion. A, 0·7-mm. soft stainless-steel wire etched at −200 mV.; B, 0·4-mm. extra-hard drawn wire etched at +1171 mV.; C, 0·4-mm. extra-hard drawn wire etched at −378 mV. Etched in 5 per cent H_2SO_4 +0·1 g./l. KCNS.

THE POTENTIOSTAT

As its name implies, this is a device which maintains an electrode at a predetermined potential with reference to a standard potential. In this work a sample of orthodontic wire is being used as the working electrode in an electrolytic cell consisting of 5 per cent H_2SO_4 +0·1 g./l. KCNS. The electrolyte therefore contains three electrodes; the orthodontic wire, a platinum auxiliary electrode, and a standard calomel electrode.

different structural phases in a metal in an electrolyte occurs at discrete potentials, and if a sample in an electrolyte has its potential varied from a negative value of say −700 mV., to a positive one of +1670 mV. (with respect to the calomel reference electrode), these critical potentials of etching will be traversed. This is effected by incrementally changing the potential which the potentiostat is required to maintain, either manually or mechanically.

The position of these etching potentials can be recorded on a chart as shown in *Fig.* 1 where the horizontal axis represents the potential, which is being changed from a negative value on the left to a positive value on the right. The vertical axis represents the current flowing whilst the potential is being changed.

This figure demonstrates the basic features of the potential sweep. As the potential increases from a negative value, the current flow changes from being negative in the region of hydrogen evolution (−700 mV.), to become positive in the active region, the passive region, the transpassivity region, and the region of oxygen evolution.

The vertical peaks represent regions of increased current flow associated with etching or selective dissolution occurring at those potentials. The maximum rate of dissolution is occurring at the peak maxima. The peak in the active region may often be shown to consist of more than one peak by refining the potentiostat electronic control parameters. If this is the case, each small peak represents a different phase in the metal. Furthermore, the peak heights show the relative proportions of the phases in the alloy. This technique provides the basis for a very sophisticated etching procedure.

POTENTIOSTATIC ETCHING

This is gradually becoming an established metallographic procedure (Edeleanu, 1957a, b; Čihal and Prazak, 1959; von Fraunhofer and Banks, 1972), but this work appears to be the first time that it has been applied to orthodontic wires. For this work a sample of wire was mounted in acrylic with prepared electrical connexions, as shown in *Fig.* 2, and metallographically polished using silicone carbide and diamond. It was then placed in the electrochemical cell, and connected to the potentiostat. It was held at the potential relative to a peak maximum of the potential/current curve for an appropriate time, then predominantly only that particular phase was found to be etched out.

Fig. 3A shows a transverse section of 0·7-mm. soft wire etched at −200 mV. The typical grain structure of Austenite can be seen with twin banding. Other inclusions are also visible. *Fig.* 3B, C show a transverse section of 0·4-mm. T.P. wire etched at two different potentials and show that, although the structure is complex, it is possible to differentiate the structures at these two different potentials.

DISCUSSION

Other authors have investigated the physical and clinical properties of stainless-steel wires. However, a fundamental factor missing from these investigations has been the correlation of these clinical and physical properties with the composition, and particularly the detailed microstructure which determines the properties of the wires.

British steel is far less costly than that which is imported for its high tensile properties and the most important property of high proof stress values. It is hoped that by a detailed study of microstructure, information could be obtained about the most satisfactory methods of manipulation and heat treatment of British wires to match and even improve upon the clinical performance of the imported ones.

This comment is directed at the *extra*-hard drawn wire, but the technique will be equally directed at problems associated with the hard drawn wires used for cribs and springs in removable appliances, particularly fracture, corrosion, soldering, and welding factors.

The potentiostat is one piece of apparatus which should assist in resolving the changes in microstructure associated with the clinical problems involving stainless-steel wire.

Acknowledgements

The authors wish to thank Professor C. F. Ballard, Dr. J. R. E. Mills, and Mr. S. G. McCallin for their encouragement and continued interest in this project; Mr. E. H. Davies of the Dental Materials Department of the Eastman Dental Institute for his helpful advice and discussion; Mr. J. Morgan for preparing the photographic material for the lecture; and Miss J. Jeffrey for her secretarial assistance.

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THE CHALLENGE OF FACIAL DEFORMITY

SIDNEY L. HOROWITZ, D.D.S.

Professor of Dentistry, and Director, Division of Orofacial Development, School of Dental and Oral Surgery, Columbia University, New York

FACIAL deformity concerns us all. It is a challenge prompted by the serious emotional, social, vocational, and ultimately economic strains suffered by those who are directly affected. It is a challenge because of the complexities with which we, as professionals, find ourselves confronted in diagnosis and physical management. Above all, it is a challenge that involves us in a commitment that is far beyond ordinary clinical obligations, for facial deformity affects not only faces but entire lives.

In our culture, reactions to deformity are almost universally negative (McWilliams, 1970). Apparently this has been so since the dawn of history. In Greek myth, Haephestus (Vulcan) was banished from Mount Olympus because he was born deformed, surely one of the earliest accounts of parental rejection. The passage of time has not helped to soften feelings of revulsion. You may recall that Oberon's blessing on the three couples in the last scene of *Midsummer Night's Dream* concludes with these words:—

> 'And the blots of Nature's hand
> Shall not in their issue stand;
> Never mole, hare-lip, nor scar,
> Nor mark prodigious, such as are
> Despised in nativity,
> Shall upon their children be.'

Since a large proportion of birth defects that result in facial deformity are neither rare nor fatal, cultural prejudices can be as much of a problem as the physical defect itself. For the patient the emotional consequences are often devastating, vocational choices are restricted, and opportunities for social interchange are curtailed.

Even the definition of facial deformity reflects subjective cultural attitudes which are based largely upon vaguely understood and poorly measured images of facial beauty. Patients, of course, are affected psychologically by these values. A few grossly overestimate the importance of even slight facial disharmony. Conversely, there are patients with very severe facial deformities who adjust to the deficit. They function effectively and productively in business and in their personal lives. Only a few psychological studies of facially disfigured patients are available (Macgregor, 1970; Stewart, 1963), and they tend to confirm that responses to facial deformity are highly subjective.

It is thus reasonable to assume that a patient would not seek help if he thought that there were no problem. What remains for us is to help to define the deformity as a deviation from some norm, and then to outline an appropriate approach for establishing a more acceptable facial balance. Unfortunately, accurate description remains one of the most elusive diagnostic problems in the physical management of facial malformation. At first glance, nothing seems more straightforward than to identify severe facial imbalance in a patient from simple clinical observation. The particular syndrome may even have a name. Describing the specific site or sites of craniofacial deformity is anything but simple, however, and real differences among experienced workers in the field are frequent and spirited.

There are other problems as well. While some congenital facial malformations, such as cleft lip and palate, are present at birth and are readily recognized, other conditions become manifest only as development proceeds. Hereditary factors have been implicated in both types, although specific genetic correlations are unclear except in the chromosomal disorders. Most of the more common facial malformations have a multifactorial aetiology and do not show Mendelian inheritance patterns. No simple genetic mechanism has been found in cleft lip and palate, and the appearance of a cleft is apparently related to the cumulative stress (from both hereditary and environmental factors) placed on the foetus as a particular developmental threshold is attained. The aetiology of mandibular prognathism is also unclear. Hereditary factors are involved in many instances (Litton, Ackermann, Isaacson, and Burton, 1970), but the long time-span during which the condition develops allows ample opportunity for environmental forces to play a role, too.

THE STRATEGY OF TREATMENT PLANNING

From the orthodontist's viewpoint the goals of treatment planning in facial deformity include:

The Twenty-fifth Northcroft Memorial Lecture presented at the Country Meeting held in Sheffield on 23 April, 1971.

(1) achievement of satisfactory jaw and occlusal relationships; (2) an acceptable alinement of teeth; (3) a harmonious relationship between the hard and soft tissues of the face; (4) an aesthetically satisfactory balance in soft-tissue contours. These aims dictate strategy in treatment, always with the understanding that it may be possible to reach the desired goals by the following alternative strategies.



Fig. 1.—Curves of the face: FN, Frontonasal; NL, nasolabial; LM, labiomental. The latter two are directly affected by dento-alveolar and maxillomandibular relationships.

The Dentition

There are two types of occlusal imbalance that affect facial appearance. First, there are relatively minor conditions such as maxillary and bimaxillary dental protrusion. These respond well to orthodontic correction and need not concern us further here. Secondly, there is a separate category of malocclusions that *result* from disturbances in craniofacial growth (Converse and Horowitz, 1966). In planning strategy, such conditions must be recognized as complex dentofacial morphological aberrations rather than simple dental malocclusions. As such they are difficult, if not impossible, to treat satisfactorily by orthodontic therapy alone. Nevertheless, frequent attempts are made to correct this type of malocclusion orthodontically, and sometimes acceptable interdigitation is obtained. Unfortunately, the orthodontic result which is so painstakingly achieved must often be undone if the facial deformity is corrected by alteration in jaw relationships. These conditions require a team approach: orthodontic preparation preoperatively; surgical correction of the facial deformity designed to improve both jaw and dental relationships; finally, postoperative orthodontic therapy to obtain the best alinement and occlusion possible (Converse, Horowitz, and Wood-Smith, 1964; Proffit and White, 1970).

Skeletal Framework

The challenge of accurately describing the human face has stimulated artists and scientists for centuries. Geometric, mathematical, and statistical methods have all proved unsatisfactory. Cephalometric studies of persons with generally pleasing facial aesthetics (Riedel, 1957; Peck and Peck, 1970) show that the dimensions and relationships of the underlying dentofacial skeletal structures fall within the ranges previously established as population norms. Facial harmony thus involves complex relationships that cannot be conveniently reduced to sets of numbers expressed as averages. Comparison of an individual patient's measurements cannot be used to establish treatment goals (Horowitz and Hixon, 1966).

Soft-tissue Balance

The two most important curves of the soft-tissue facial profile originate at the lips. They are the *nasolabial* curve and the *labiomental* curve. (*Fig.* 1; Case, 1921). Both curves form graceful concavities when the lips are relaxed with the teeth slightly apart. In a well-balanced face, therefore, the lips close with ease in repose and the curves are neither abnormally deep nor straight.

Longitudinal studies of normal facial growth have provided orthodontists with a reservoir of information that is of great value in planning treatment strategy, but more longitudinal investigations of children with specific types of facial deformity are urgently needed. Such studies are particularly important when considering the optimum time for treatment. Despite our knowledge of normal facial growth, specific information regarding the most appropriate age for performing corrective surgical procedures in facial malformations is limited. This has produced some sharp differences in treatment strategies for similar deformities.

In the United States, for example, mandibular prognathism corrections, with few exceptions (Biederman, 1967), are done in late adolescence at the earliest. Knowles (1970), on the other hand, has presented impressive results of such corrections in children. True longitudinal data on mandibular prognathism are lacking, but a cross-sectional study of this condition has recently been published in Japan and indicates that the mandible becomes more prominent with age, while the maxilla shows little change (Susami, 1969). This is no different than the expected normal growth pattern, and thus the problem remains unresolved.

Cephalometric measurements have provided no adequate predictors of facial growth either in

normal children or in individuals with mandibular prognathism. There is thus no satisfactory way at present of determining in which child the growth pattern would be so abnormal as to demand immediate preventive surgical intervention. Some of the early operations are undoubtedly useful and possibly even necessary; the question is: which ones?

The factor of maturation in relation to facial growth must therefore be considered in deciding strategy, particularly in those deformities that show imbalance in the profile. Both the mandible and the nose continue to grow well into the adolescent period, and treatment designed to establish satisfactory nose–chin balance is preferably delayed until late adolescence. This is not the case for all facial defects. The external ear reaches adult proportions early in life, and reconstructive procedures for ear deformities can therefore be started during the childhood years.

METHODS AND TECHNIQUES OF PLANNING

Once a general strategy has been determined, specific planning requires the standard orthodontic diagnostic records: study models, roentgenograms, and photographs. The study models and X-rays are of special value.

Study Models

Paradoxically, although the teeth and occlusion are often greatly disturbed in lower face malformations, the dentition provides the most important guide in planning therapy. The models may be shifted anteroposteriorly or sectioned in order to simulate corrections (*Figs.* 2, 3) —a technique first described by Willett (1927) and later elaborated by Barrow and Dingman (1950).

Articulator mounting is desirable, since occlusal equilibration should be planned preoperatively. Few reports mention the need for equilibration, but when one considers that a major alteration in the jaw relationships brings the teeth into unaccustomed articular relationships, the need is apparent. A lifetime of occlusal wear must be provided for the patient within a brief period either preoperatively or at the time of operation (*Fig.* 4).

The sectioned-cast technique works well in planning for mandibular prognathism, open-bite

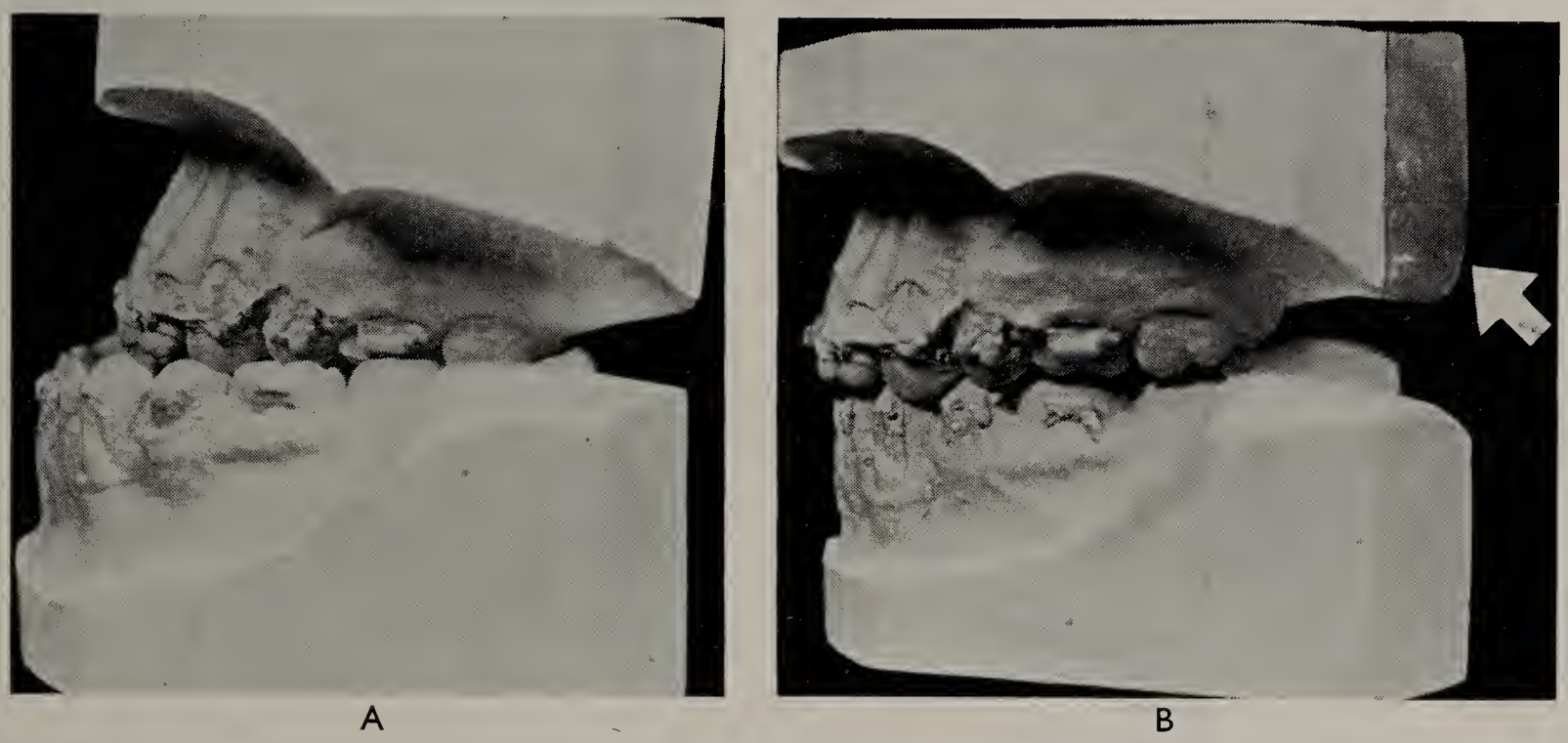


Fig. 2.—Planning correction of mandibular prognathism (ramus section). A, Preoperative model. B, Correction simulated by moving the upper study model forward. The amount of mandibular retraction required is indicated by the wax added to the maxillary cast (arrow).



Fig. 3.—Planning for correction of mandibular prognathism (section in the mandibular body). The amount of setback is indicated by the distance from the front of the platform of the lower cast (arrows).



Fig. 4.—The occlusal equilibration required for satisfactory interdigitation in the correction of mandibular prognathism.

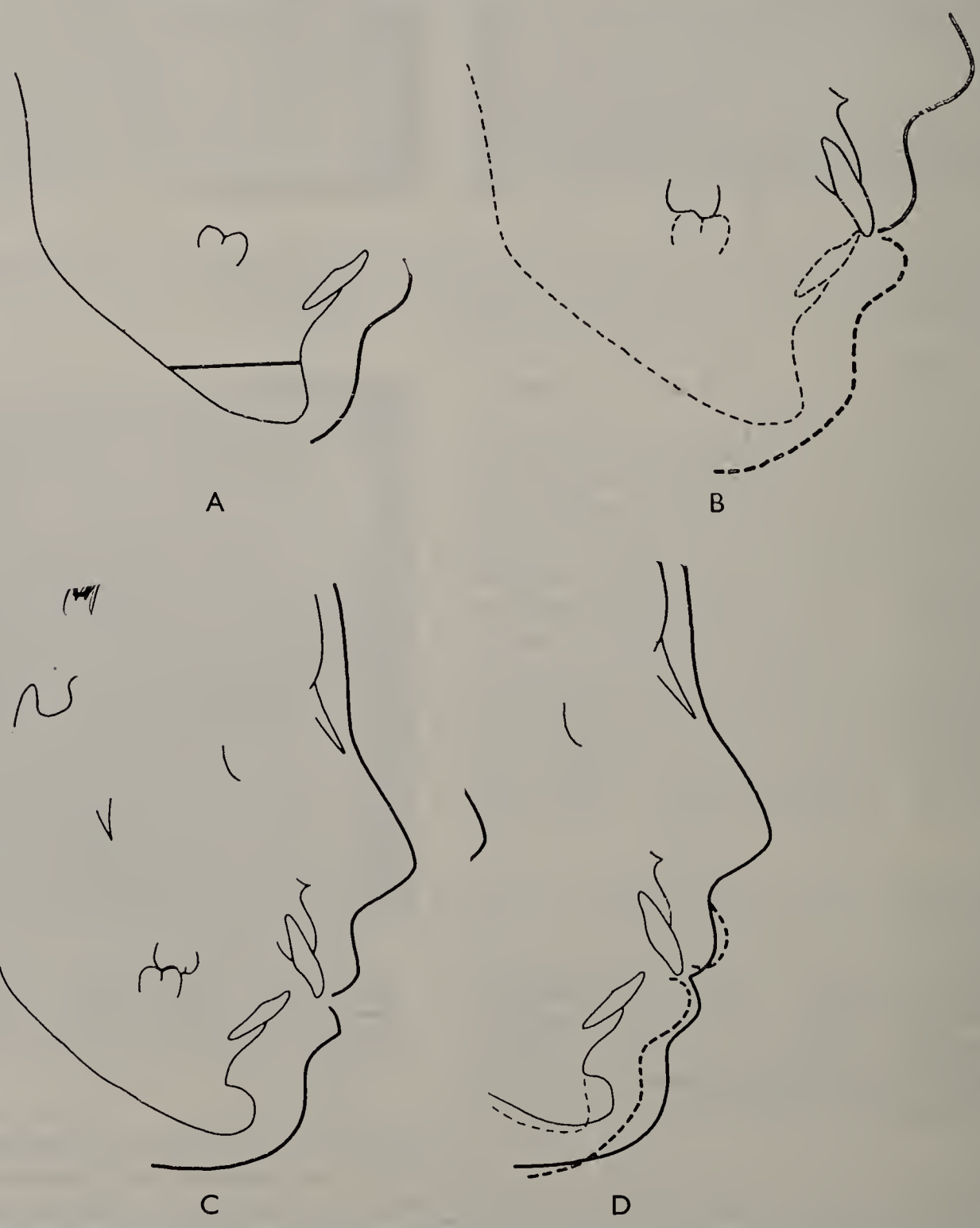


Fig. 5.—Cephalometric planning for profile change. A, Cut-out of the lower jaw. The horizontal line indicates the site of the osteotomy. B Cut-out moved into a hypothetical normal occlusion, providing a guide to the desired new position for the *pogonion* point. C, Postoperative result following a horizontal osteotomy of the mandible beneath the tooth roots, with advancement of the chin point. D, Preoperative and postoperative tracings superimposed.

corrections (Converse and Horowitz, 1969), and for the maxillary protrusions. In the latter, careful attention must be paid to establishing satisfactory postoperative axial inclination of the maxillary incisors at the time of operation, since

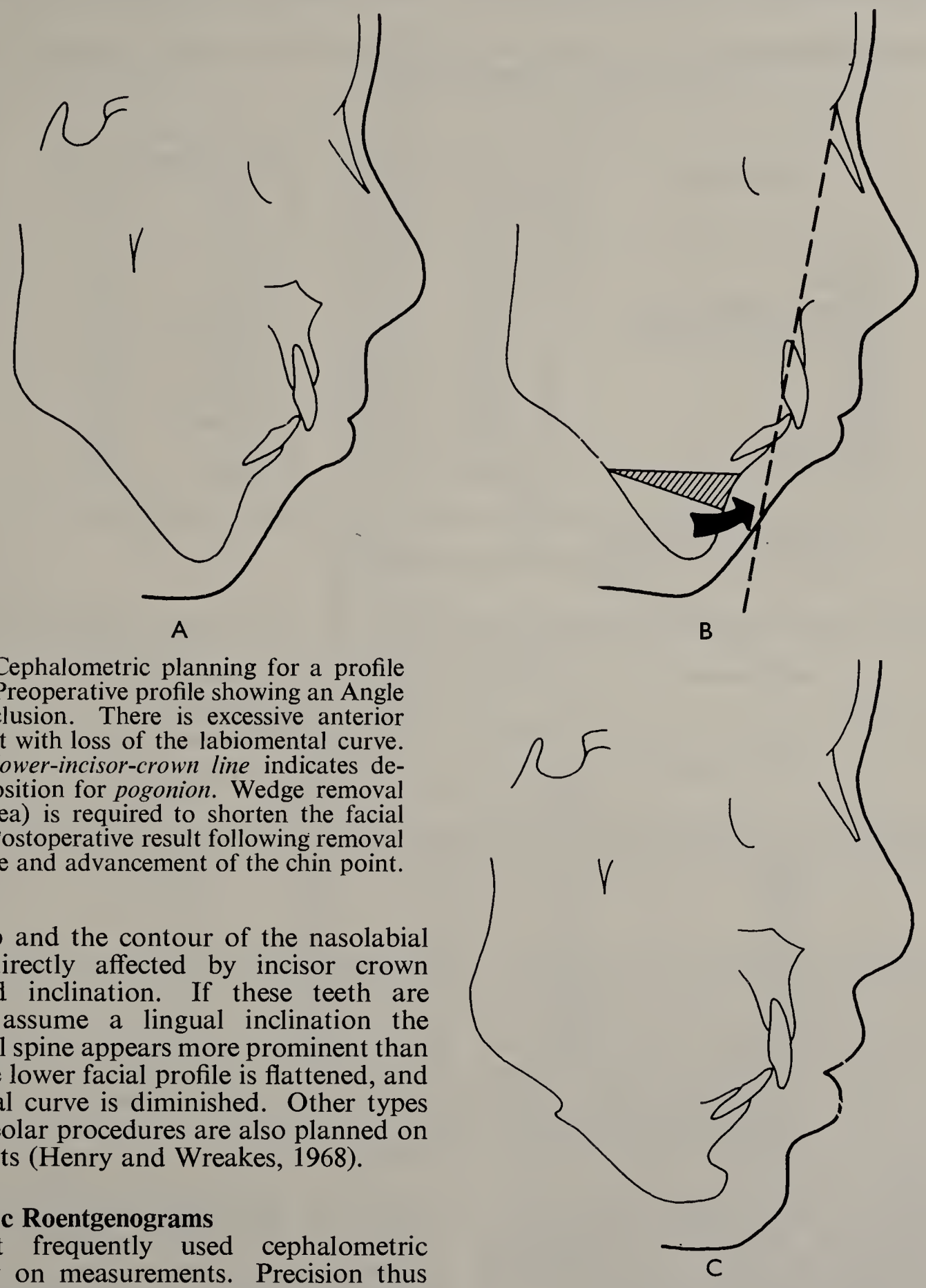


Fig. 6.—Cephalometric planning for a profile change. A, Preoperative profile showing an Angle Class I occlusion. There is excessive anterior facial height with loss of the labiomental curve. B, *Nasion–lower-incisor-crown line* indicates desired new position for *pogonion*. Wedge removal (hatched area) is required to shorten the facial height. C, Postoperative result following removal of the wedge and advancement of the chin point.

the upper lip and the contour of the nasolabial curve are directly affected by incisor crown position and inclination. If these teeth are allowed to assume a lingual inclination the anterior nasal spine appears more prominent than it should, the lower facial profile is flattened, and the nasolabial curve is diminished. Other types of dento-alveolar procedures are also planned on sectioned casts (Henry and Wreakes, 1968).

Cephalometric Roentgenograms

The most frequently used cephalometric analyses rely on measurements. Precision thus becomes confused with objectivity in case evaluation, and error that Alfred North Whitehead described as the ' fallacy of misplaced concreteness '. Moreover, when a facial deformity is clearly apparent clinically, it is to be expected that at least some cephalometric values will differ from average ' norms ' by several standard deviations. Conventional techniques of cephalometric analysis therefore offer little diagnostic guidance in planning correction of facial deformities.

Non-metric techniques for using the cephalogram depend upon the evaluation of certain relationships that are judged more or less subjectively. They have been particularly helpful in simulating profile changes that might result from surgical/orthodontic procedures. Some that we have found useful are:—

1. A cut-out technique for evaluating nose–chin balance. In maxillary protrusion cases, for example, a change in profile can be obtained by the maxillary setback procedure. In the less

severe protrusions, or when maxillary setback is contra-indicated because of extensive restorations, a chin-implant may suffice. In either instance the expected change can be reasonably predicted by either moving the maxillary cut-out posteriorly or moving the mandibular cut-out anteriorly into simulated Class I incisal contact (*Fig.* 5). A similar technique is useful in obtaining some measure of the facial change to be expected from correction of mandibular prognathism.

2. In Class I bimaxillary protrusions the chin may appear underdeveloped because of the facial convexity. A line drawn from the nasion through the lingual surface of the lower incisor crown profile provides a guide to the size of chin implant or chin advancement that will be required to obtain an aesthetically pleasing new position for the pogonion point.

3. Mandibles that are overdeveloped in the superior–inferior dimension show distortion of the labiomental curve. Anterior face height must be reduced in order to achieve profile improvement in these patients. A procedure that includes both removal of a wedge of bone beneath the tooth roots and advancement of the mental symphysis to the N-lower incisor line both reduces face height and provides a more prominent chin point. The anticipated results may be simulated on the cephalogram tracing (*Fig.* 6).

Table I.—Angular Measurements of Subjects with Mandibular Prognathism compared with those of Control Subjects

Measurement	Control (n=30)		Mandibular Prognathism (n=36)	
	Mean	S.D.	Mean	S.D.
NSAr	124·1	4·3	119·3**	6·5
SArGo	144·9	6·5	142·9	9·7
ArGo–mandibular plane	124·4	5·4	133·7***	8·1
Mandibular plane–Pold	68·1	6·1	58·8***	8·7
SNPr	83·9	3·7	83·0	4·2
SNA	79·5	3·9	78·6	4·2
SNB	79·2	3·4	85·7***	5·1
SNPr	80·8	3·4	87·0***	4·2
SNA–SNB	0·3	1·8	−7·1	4·4
NSGo	103·9	3·7	96·9***	5·5

**$P<0·01$; ***$P<0·001$.
From Horowitz, Gerstman, and Converse (1969).

Table II.—Linear Measurements of Subjects with Mandibular Prognathism compared with those of Control Subjects

Measurement	Control (n=30)		Mandibular Prognathism (n=36)	
	Mean (mm.)	S.D.	Mean (mm.)	S.D.
PtmNa	51·7	3·9	47·8***	3·3
GoB′	74·4	6·3	73·7	7·0
B′P′	9·8	2·5	11·5*	2·9
GoP′	84·2	6·4	85·2	6·4
SN	75·9	4·7	72·0**	4·9
SGo	87·7	7·0	83·2**	6·3
NP′	134·7	7·2	133·4	8·3
SAr	38·2	3·9	35·6	4·1
ArGo	53·7	5·1	52·4	6·2

*$P<0·05$; **$P<0·01$; ***$P<0·001$.
From Horowitz, Gerstman, and Converse (1969).

DIFFERENTIAL DIAGNOSIS OF FACIAL DEFORMITY

To illustrate some of the fundamental difficulties encountered in describing even a familiar facial deformity accurately, I have chosen to

discuss *mandibular prognathism* as a representative model. So many excellent reports relating to this condition have originated in the United Kingdom (Hopkin, 1963, 1965; Mills, 1966; Knowles, 1970) that it is possible to proceed directly to the heart of an apparently simple question that we once thought satisfactorily answered: 'What is the nature of mandibular prognathism?'

In my opinion the best clinical definition of this malformation was written long before the term 'mandibular prognathism' was used. It is characteristically succinct: 'the lower jaw projecting too far forwards, so that the fore-teeth pass before those of the upper jaw, when the mouth is shut; which is attended with inconvenience, and disfigures the face.' (J. Hunter, 1778).

The clarity of these observations provided a starting point for our own investigations of craniofacial relationships in mandibular prognathism. Two essential *clinical* criteria for the condition could be established without difficulty: first, a facial disfigurement in which the lower portion of the face appears unduly prominent, and secondly, a Class III (Angle) malocclusion of the teeth.

A detailed comparison between an adult group of subjects with mandibular prognathism and a group of unaffected persons drawn from the population at large has been published elsewhere and need only be summarized briefly here (Horowitz, Gerstman, and Converse, 1969).

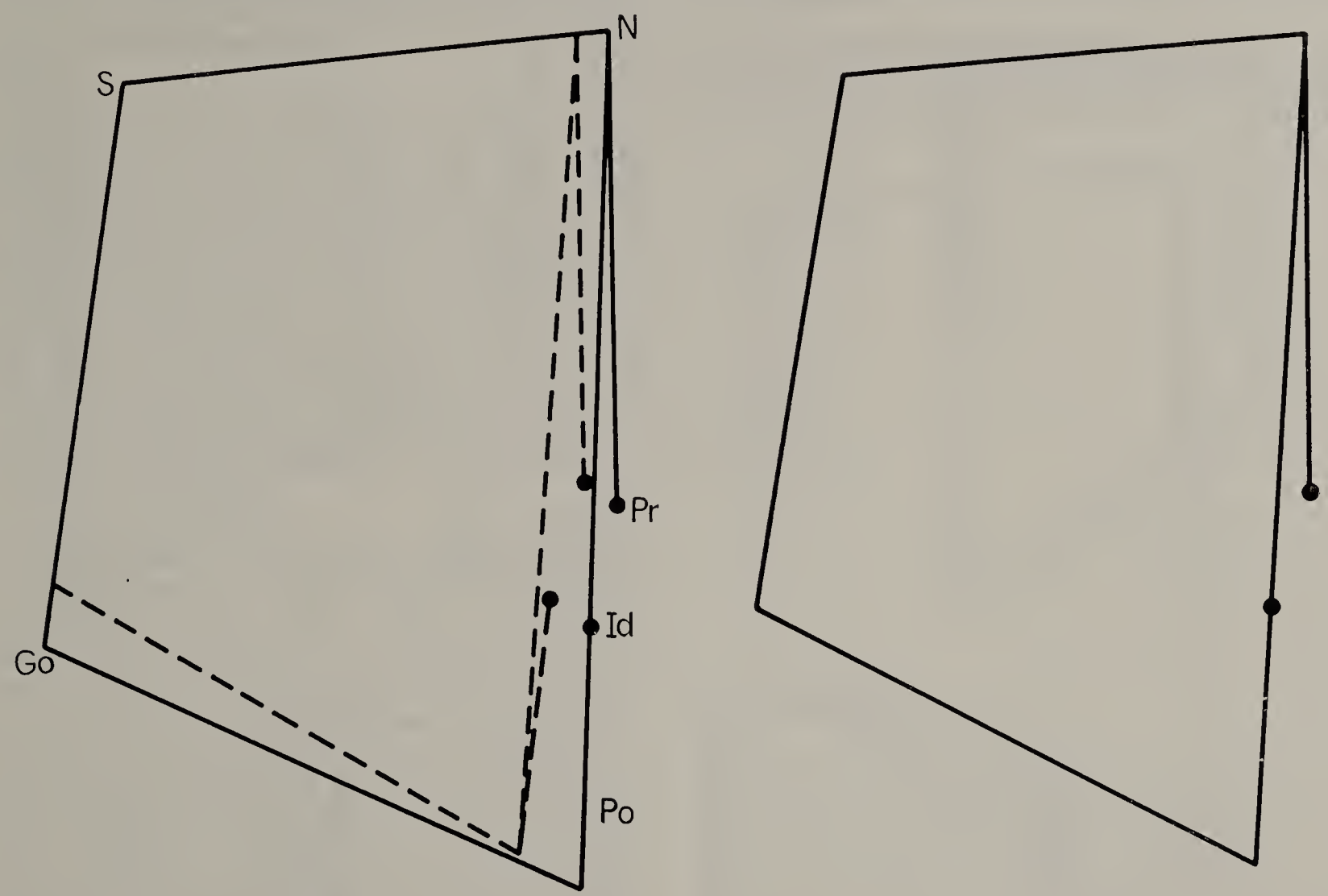


Fig. 7.—A, Control polygons (*see* text). S, Sella. N, Nasion, Pr, Prosthion. Id, Infradentale. Po, Pogonion. Go, Gonion. Solid line, male control. Dashed line, female control. B, Average male/female polygon.

Using traditional methods of analysis, 19 measurements were compared separately. For example, the average maxillary length in subjects with mandibular prognathism was compared with the average maxillary length found in the control group. The analysis shows clearly that persons with mandibular prognathism differ significantly from the general population in several craniofacial dimensions and relations (*Tables I, II*).

When each measurement is evaluated independently it is difficult to determine the relative importance of any particular variable in separating the deformity group from the control group. Measurements that show similar significant differences (the same probability values) must be considered as contributing with equal weight to the total differences between the groups. Since this seemed unlikely, we re-evaluated the same data using multivariate statistical techniques that make it possible to analyse the relationship of all of the measurements simultaneously. Using an

appropriate computer program, the 19 measurements were deployed in a way that reflected the *relative* contribution and importance of each in distinguishing individuals with mandibular prognathism from unaffected persons.

The computer program sought the best combination of variables by which the two groups could

A combination of 5 of the 19 variables is sufficient to discriminate significantly between the group with mandibular prognathism and the control group. In order of importance, these are:—

1. SNA–SNB difference. This is a reflection of one of the original clinical criteria.

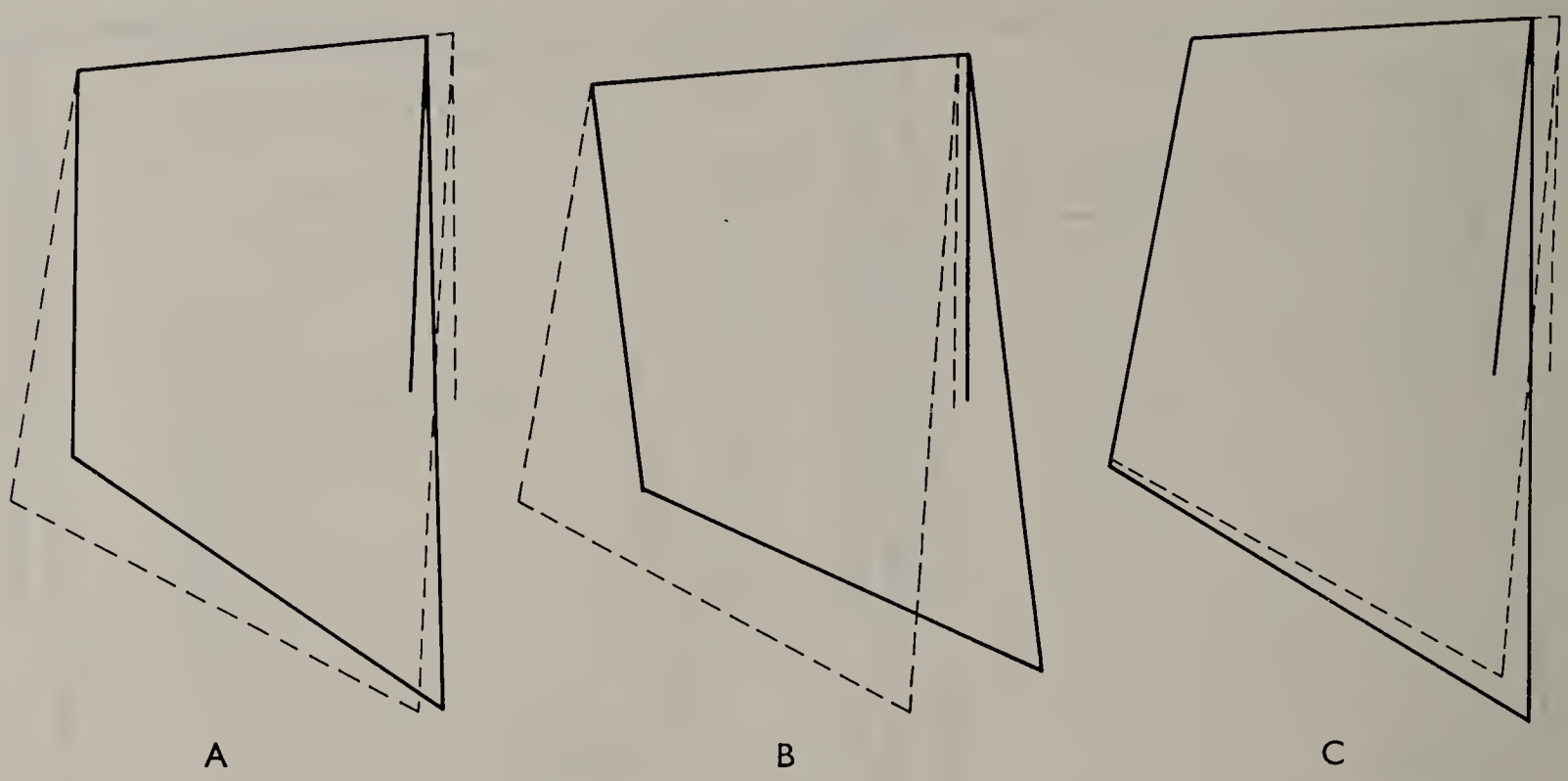


Fig. 8.—A, Type I prognathism: rotation with small cranial base. B, Type II prognathism: rotation with normal cranial base. C, Type III prognathism: no rotation; small cranial base. D, Type IV prognathism: rotational ' bulldog ' type. E, Type V prognathism: generalized underdevelopment.

be separated from one another. The hierarchical ranking of measurements obtained serves to define the *pattern* of craniofacial lines and angles that best describes mandibular prognathism. If the separate measurements are thought of as pieces in a puzzle the computer program helps us to understand how the pieces fit together. In other words, it shows the *interdependence* of the pieces within an overall pattern.

2. SN length. On average this measurement is shorter in the group with mandibular prognathism. More important, the appearance of this variable at step 2 of the analysis is information independent of jaw relationships. *It could not have been predicted from the clinical criteria.* Other investigators have also reported small SN measurements, but multivariate analysis indicates the relative importance of the anterior cranial

base as a contributing factor in the morphology of mandibular prognathism.

3. The gonial angle. This is more obtuse in the group with prognathism.

4. The length of the mandible. This is longer in the group with prognathism.

5. The position of the maxilla. The maxilla is situated more posteriorly relative to the cranium in persons with mandibular prognathism (angle SNPr).

One of the most intriguing aspects of multivariate analysis lies in the new insights obtained when the *pattern* is considered rather than taking the individual measurements separately. New and unsuspected information develops because relationships become the important focus rather than the single comparisons. When considered independently the variables, mandibular body length and SNPr, showed no difference between the group with prognathism and the control group, but *within the total pattern of craniofacial relationships* they assumed a significance as discriminating characteristics.

Taken together the research findings of other investigators and ourselves characterize mandibular prognathism as a complex condition caused by growth disturbances that affect the anterior cranial base, the position of the glenoid fossa, the shape and size of the mandible, and the position as well as the size of the maxilla. It is clear that the clinical picture may arise from more than one craniofacial pattern, and that areas distant from the mandible may be the sites of growth disturbance. Despite its continuing value as a clinical descriptive term, mandibular prognathism is a positive misnomer in some cases and at the least misapplied in others.

PATTERN MATCHING

Another approach to the use of the cephalometric X-ray in case evaluation is through *pattern matching*. This simple and rapid visual technique depicts craniofacial relationships without regard for specific angular and linear measurements. It is based on the construction of a diagram that connects selected landmarks chosen by the investigator or clinician. Diagrams are familiar in orthodontics (Björk, 1947; Margolis, 1947) although they have not been used for pattern matching.

The technique that we have developed employs a diagram constructed on the cephalogram tracing using the following landmarks and planes: nasion, sella, gonion (intersection of tangents to the posterior border of the ramus and to the lower border of the mandible), mandibular plane, nasion–pogonion line, and the points prosthion and infradentale. Control diagrams are required for comparison standards, and these we obtained from cephalogram tracings of 25 male and 25 female adult subjects who had untreated Angle Class I occlusion. Three average polygons were constructed: one for the female sample, one for the male sample, and a combined male/female diagram (*Fig.* 7). Separate male and female polygons are required in assessing pattern differences in individual patients, as the diagrams differ substantially.

Pattern Matching in Differential Diagnosis

The model of mandibular prognathism provided a convenient means of testing the clinical usefulness of pattern matching. Our working hypothesis was predicated on the research findings, which had suggested that different morphological combinations could produce a similar clinical picture in this condition. Starting with the clinical definition, then, we wished to answer two questions: first, how many different patterns of mandibular prognathism exist, and, secondly, the frequency with which each occurs.

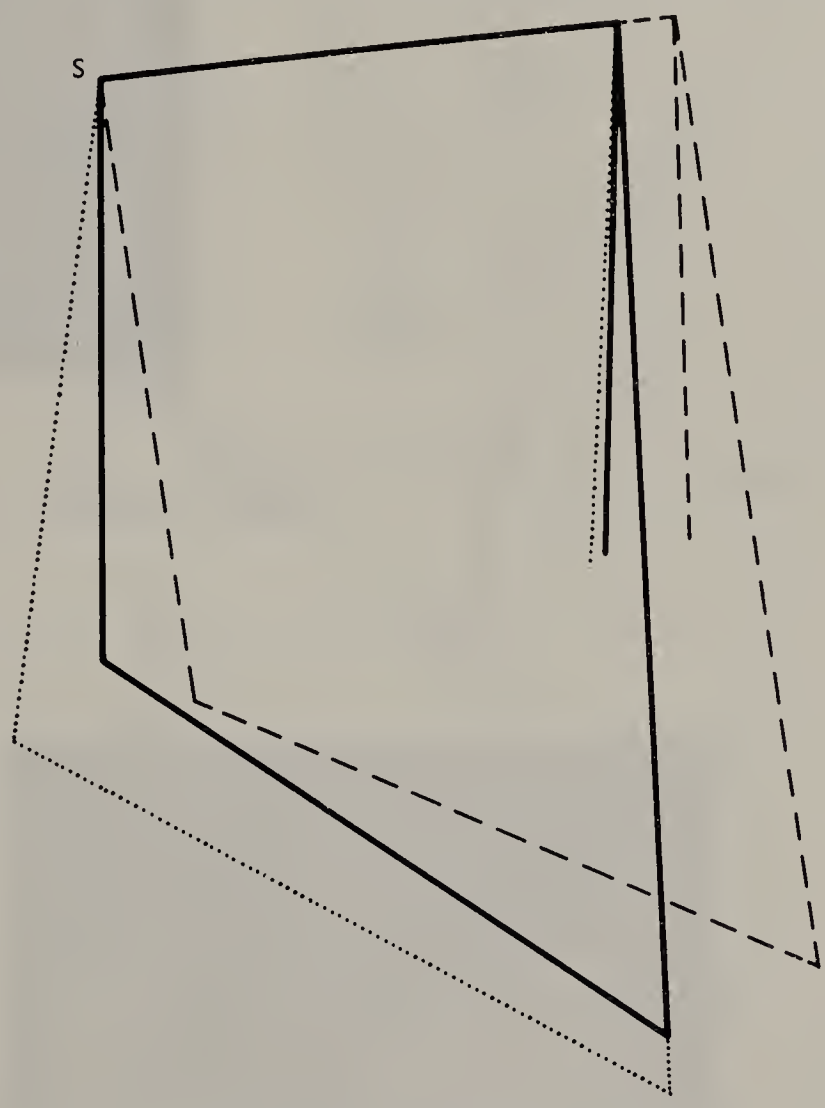


Fig. 9.—Polygons of the three most common types of prognathism superimposed at apex S. —, Type I. – – –, Type II. . . . . ., Type III.

Cephalometric roentgenograms of 51 adult individuals who met our clinical criteria for mandibular prognathism (i.e., facial disfigurement plus Class III occlusion) were available for study. The polygon diagram of each individual subject was matched against the appropriate male or female control pattern and variations in craniofacial pattern were identified by inspection. These variants were divided into separate

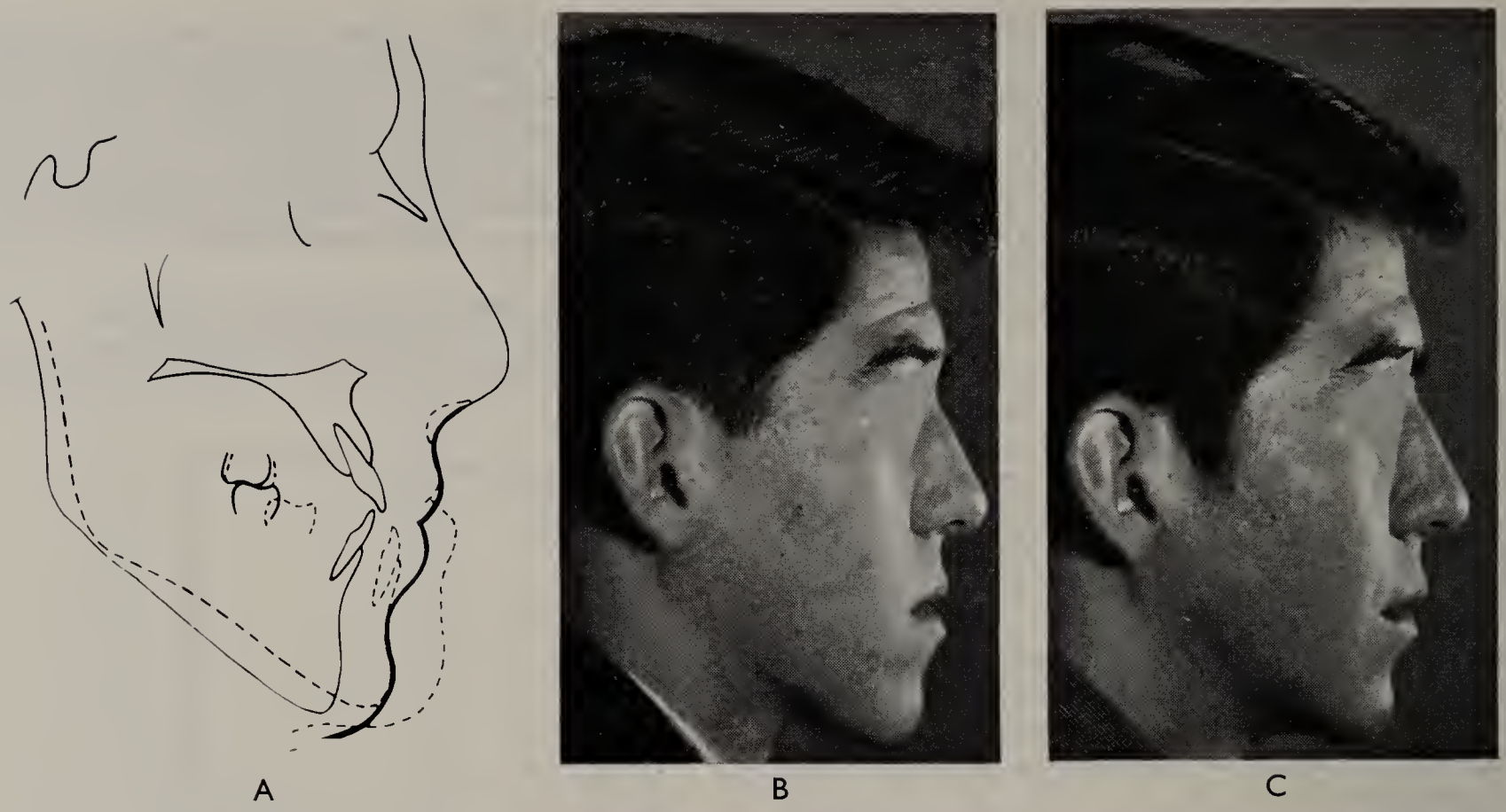
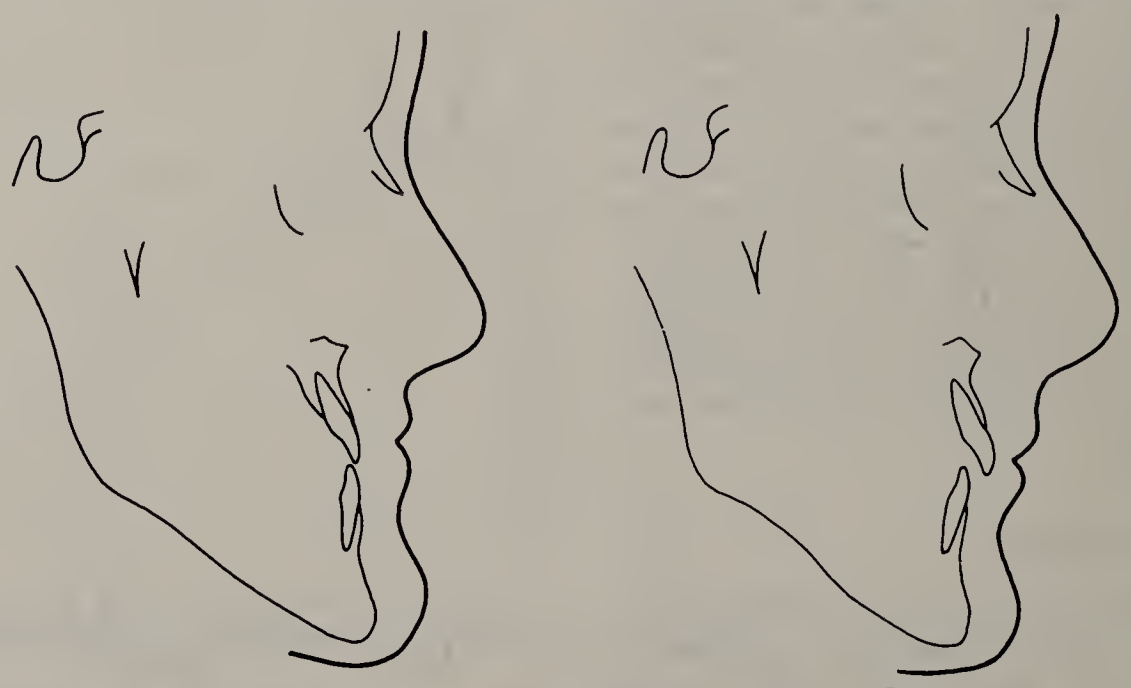


Fig. 10.—A case of Type I prognathism. A, Superimposed pre- and postoperative cephalograms. B, Preoperative profile. C, Postoperative profile.



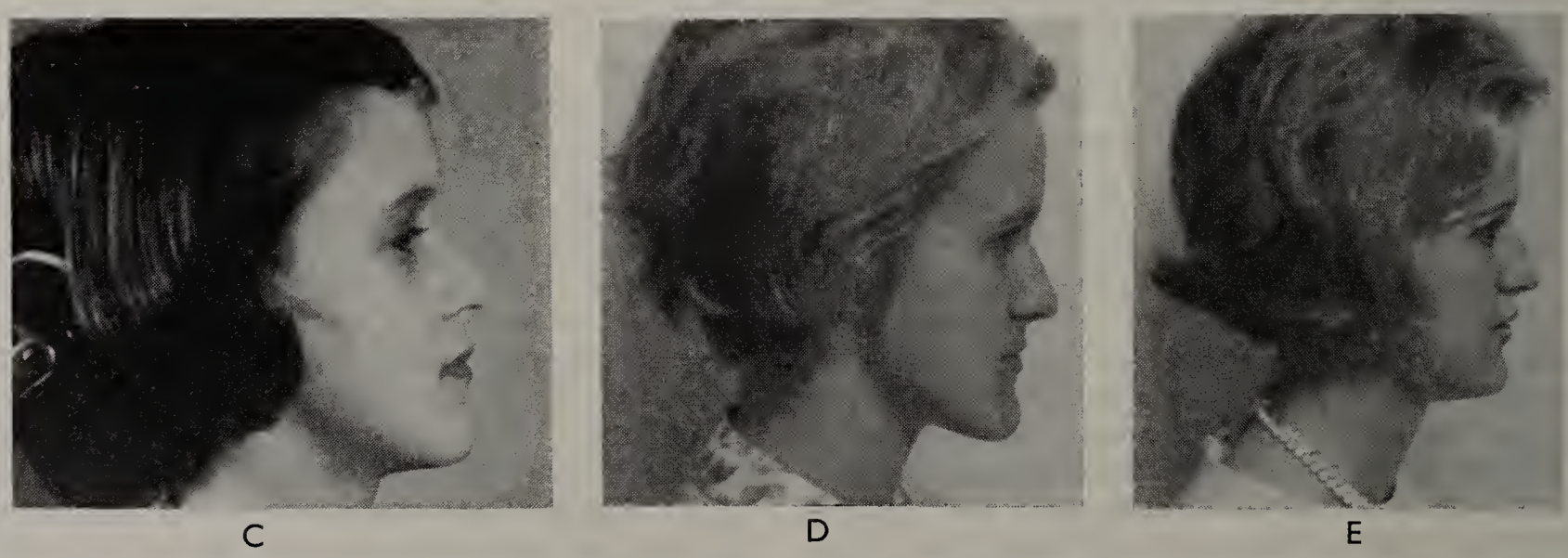


Fig. 11.—A case of Type II prognathism. A, Preoperative cephalogram. B, Postoperative cephalogram. C, Facial profile at age 12 years. D, Preoperative facial profile at age 21 years. E, Postoperative facial profile.

categories on the basis of differences in the angle nasion–sella–gonion. Another measure might have been used as a reference, but this particular angle was selected as having potential value in separating subjects with mandibular prognathism from one another because multivariate analysis had indicated the importance of the SN measure in the pathogenesis of the condition.

Five distinctly different craniofacial patterns of mandibular prognathism were determined, based on rotational movement of the polygon around the apex *S*. The frequencies of each type varied substantially.

In *Type I* (approximately 50 per cent of the sample) the apex angle is acute, the SN length is short, and NPr falls behind the N–pogonion plane (*Fig.* 8A). *Type II* (20 per cent) shows a much more acute apex angle, NPr is behind the N–pogonion plane, and the SN length is similar to that of the control diagram (*Fig.* 8B). In contrast, it is the apex angle in *Type III* (20 per cent) that is similar to the control pattern, the

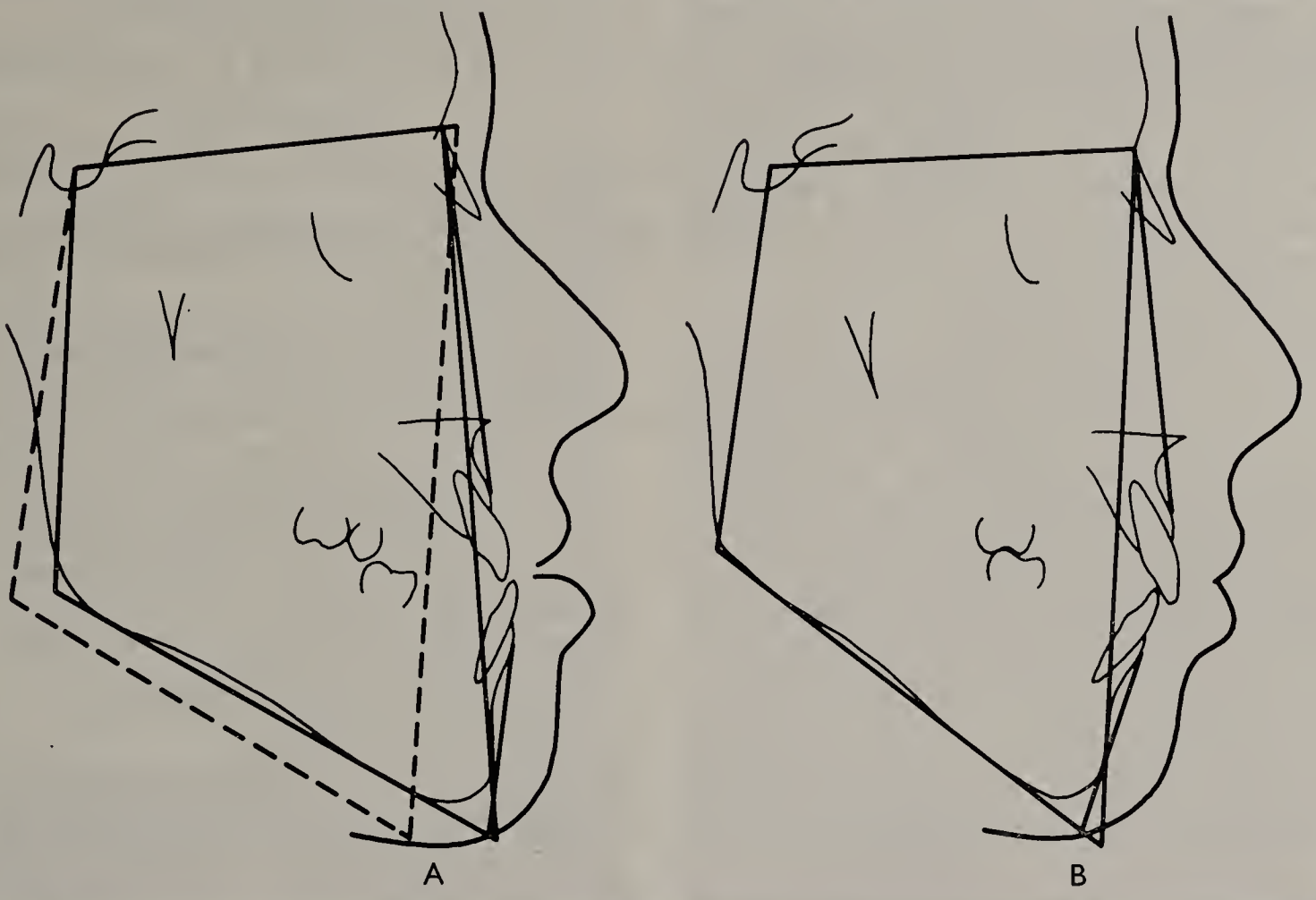


Fig. 12.—A case of Type IV prognathism. A, Preoperative cephalogram with—patient's polygon and – – – control polygon. B, Postoperative cephalogram. C, Preoperative profile. D, Postoperative profile.

SN length being short, and NPr being posterior to N–pogonion (*Fig.* 8C). *Type IV* (>5 per cent) is unusual: NPr is *ahead* of N–pogonion, SN and the mandible are both relatively long, and the apex angle is acute (*Figs.* 8D, 12). The least frequent pattern is *Type V* (<5 per cent), in which the SN and mandible length are short, and NPr is behind N–pogonion (*Fig.* 8E). The apex angle is similar to that of the control diagram. In all types the gonial angle is obtuse. The three types most commonly found (I, II, III) account for 90 per cent of our sample and show widely different polygon patterns (*Figs.* 9, 10, 11).

While the clinical usefulness of differential diagnosis through pattern matching remains to be explored more intensively, the present findings suggest that different strategies for treatment (i.e., different surgical/orthodontic approaches) may have to be developed to meet particular needs. Comparison of preoperative and post-operative patterns in a series of patients with mandibular prognathism who have been corrected by a variety of surgical procedures is in progress in our laboratory. Preliminary results of this work indicate that the pattern-matching technique will prove useful both in diagnosis and in the systemic evaluation of craniofacial changes brought about by surgical treatment.

SUMMARY

Facial deformities present complex problems in diagnosis and treatment planning that challenge the most experienced clinician. Using mandibular prognathism as a model of a well-defined clinical condition, research findings have been applied to the clinical differential diagnosis of this deformity. Five discrete types of mandibular prognathism have been defined by the technique of cephalometric *pattern matching*, and the relative incidence of each determined. *Pattern matching* appears potentially useful both in case analysis and in the evaluation of post-treatment changes in facial proportions.

Acknowledgements

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CHARACTERISTICS OF SUPERNUMERARY TEETH IN THE PRIMARY AND PERMANENT DENTITION

G. S. TAYLOR, B.D.S., F.D.S., D.Orth.

Bristol Dental Hospital and South West Regional Hospital Board

It is well known that supernumerary teeth occur more frequently in the permanent dentition than in the primary dentition. The literature relating to supernumerary teeth consists mainly of clinical descriptions and it is difficult to assess the frequency of this anomaly. It may be that supernumerary teeth in the primary dentition have less effect upon adjacent teeth than do supernumerary teeth in the permanent dentition, and they may erupt and be exfoliated without having been noticed by parents. Spacing which is frequently present in the primary dentition may allow extra teeth to be accommodated without producing irregularity. Many children reach the age at which their permanent incisors have erupted before they have a dental examination.

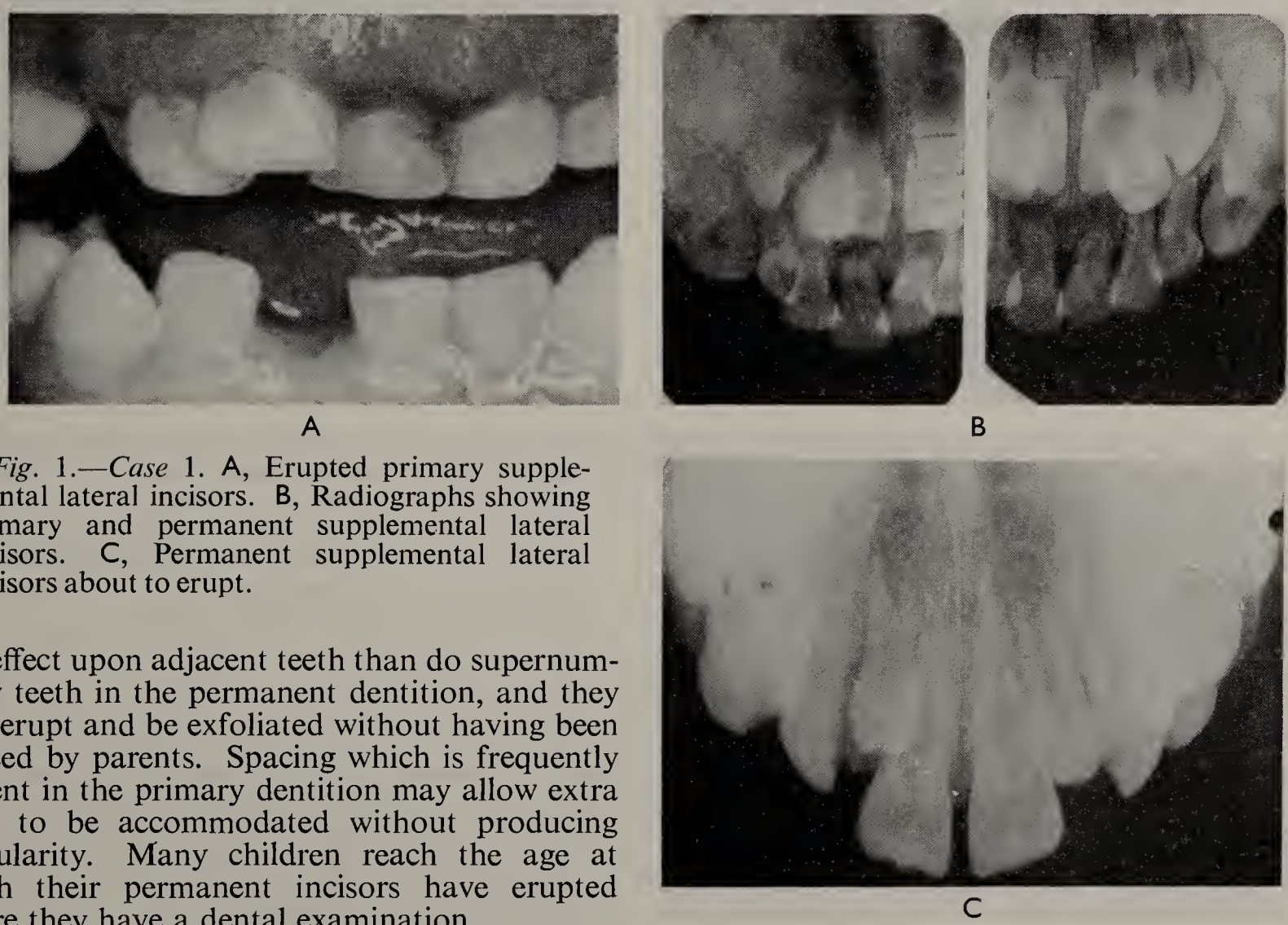


Fig. 1.—*Case* 1. A, Erupted primary supplemental lateral incisors. B, Radiographs showing primary and permanent supplemental lateral incisors. C, Permanent supplemental lateral incisors about to erupt.

Grahnén and Granath (1961) assessed the frequency of supernumerary teeth in the primary dentition as 0·3 per cent. A further study by Grahnén and Lindahl (1961) found the frequency in the permanent dentition to be between 1·7 and 3·1 per cent.

Several writers refer to the fact that supernumerary teeth may be present in both the primary and the secondary dentitions of the same patient but few details are given. Grahnén and Granath (1961) record 20 patients having supernumerary teeth in the primary dentition. In 6 of their patients, supernumerary teeth were found in the corresponding region in the permanent dentition. Further, more detailed accounts of supernumerary teeth in both the primary and permanent dentitions of 8 patients were described by Templar Barritt (1942), Munroe (1952),

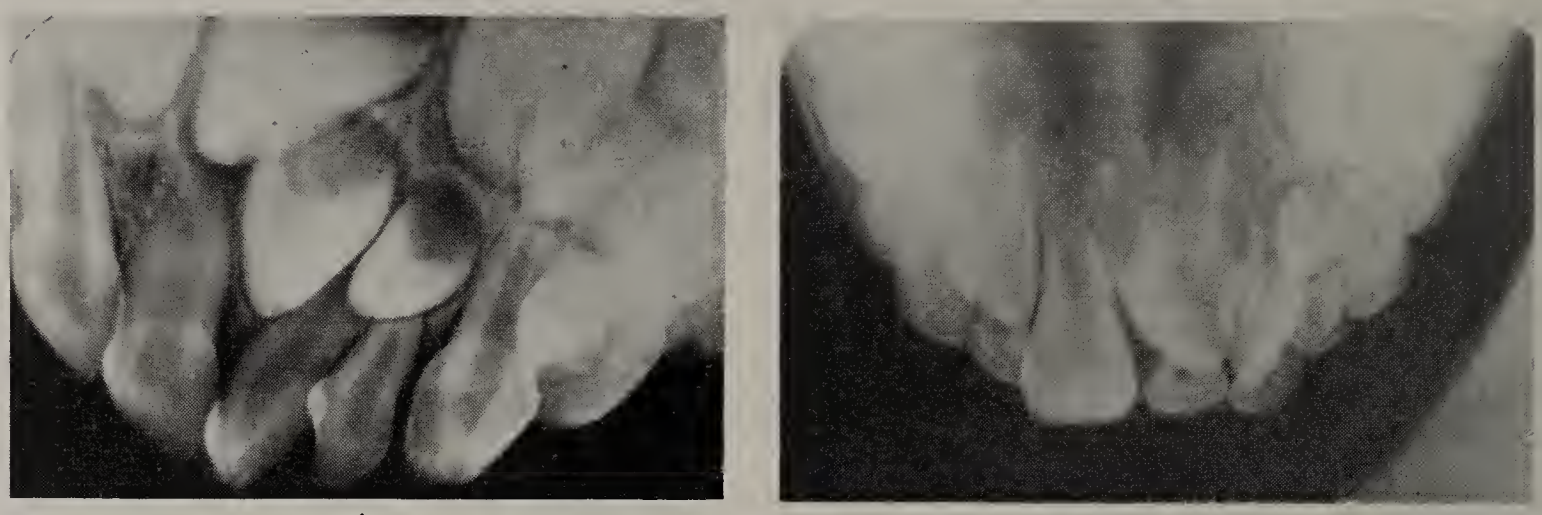
Presented at the Country Meeting held on 22 April, 1971.

Townend (1953), Robertson (1962), and Duffy (1963).

Supernumerary teeth occur most frequently in the maxillary incisor region. Stafne (1932) examined 48,550 consecutive dental patients and found 500 supernumerary teeth, 246 of which were associated with upper central and lateral incisors. Lind (1959), in a sample of 1716 patients who had been referred to an orthodontic clinic, found 60 supernumerary teeth, of which 49 were associated with either the upper central or lateral incisors.

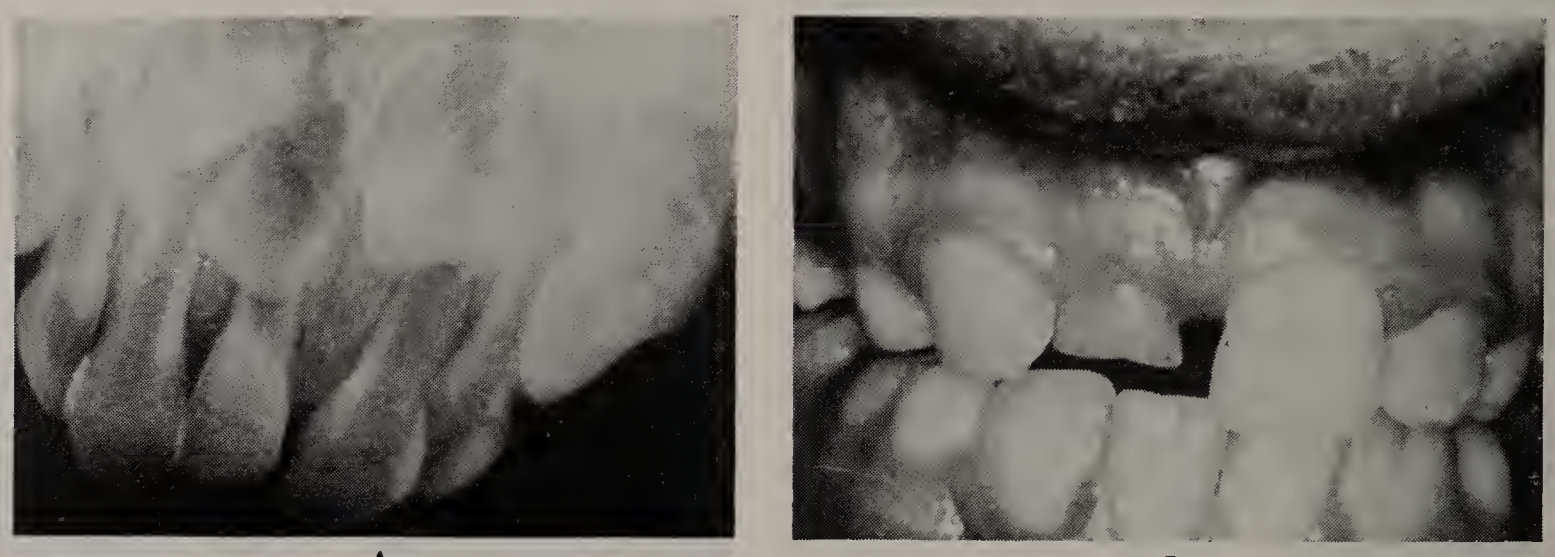
Several methods of classifying supernumerary teeth have been suggested. Howard (1967) does so on the basis of their shape. He divides supernumeraries into four categories; small peg-shaped or conical teeth; barrel-shaped teeth, that are invaginated and tuberculate; odontomes, having no regular shape; and incisiform teeth. This last category of supernumerary tooth closely resembles adjacent teeth and the teeth are often called ' supplemental '.

Magnusson (1959) found that primary supernumerary teeth were usually normal in shape and thus they can be regarded as supplemental, and that the upper lateral incisor region was particularly affected. The work of Howard (1967) and Foster and Taylor (1969) shows that permanent supernumerary teeth exhibit greater variety in shape and position.



A B

Fig. 2.—*Case* 2. A, Erupted primary supplemental lateral incisor and unerupted conical supernumerary distal to $\underline{|2}$. B, Occlusal radiograph showing retention of $\underline{|AB}$, delayed eruption of $\underline{|12}$, and a supernumerary.



A B



C

Fig. 3.—*Case* 3. A, Erupted midline primary supplemental incisor and unerupted midline supernumerary tooth at 19 months. B, Typical presentation appearance of patient aged 9 years 9 months with retention of $\underline{A|}$ and delayed eruption due to a supernumerary tooth. C, Retained $\underline{A|}$ and supplemental central incisor.

The purpose of this communication is to present details of 11 patients having supernumerary teeth in both the primary and permanent dentitions. Five patients are described in greater detail. The relationships between these teeth are discussed and compared with similar cases reported in the literature.

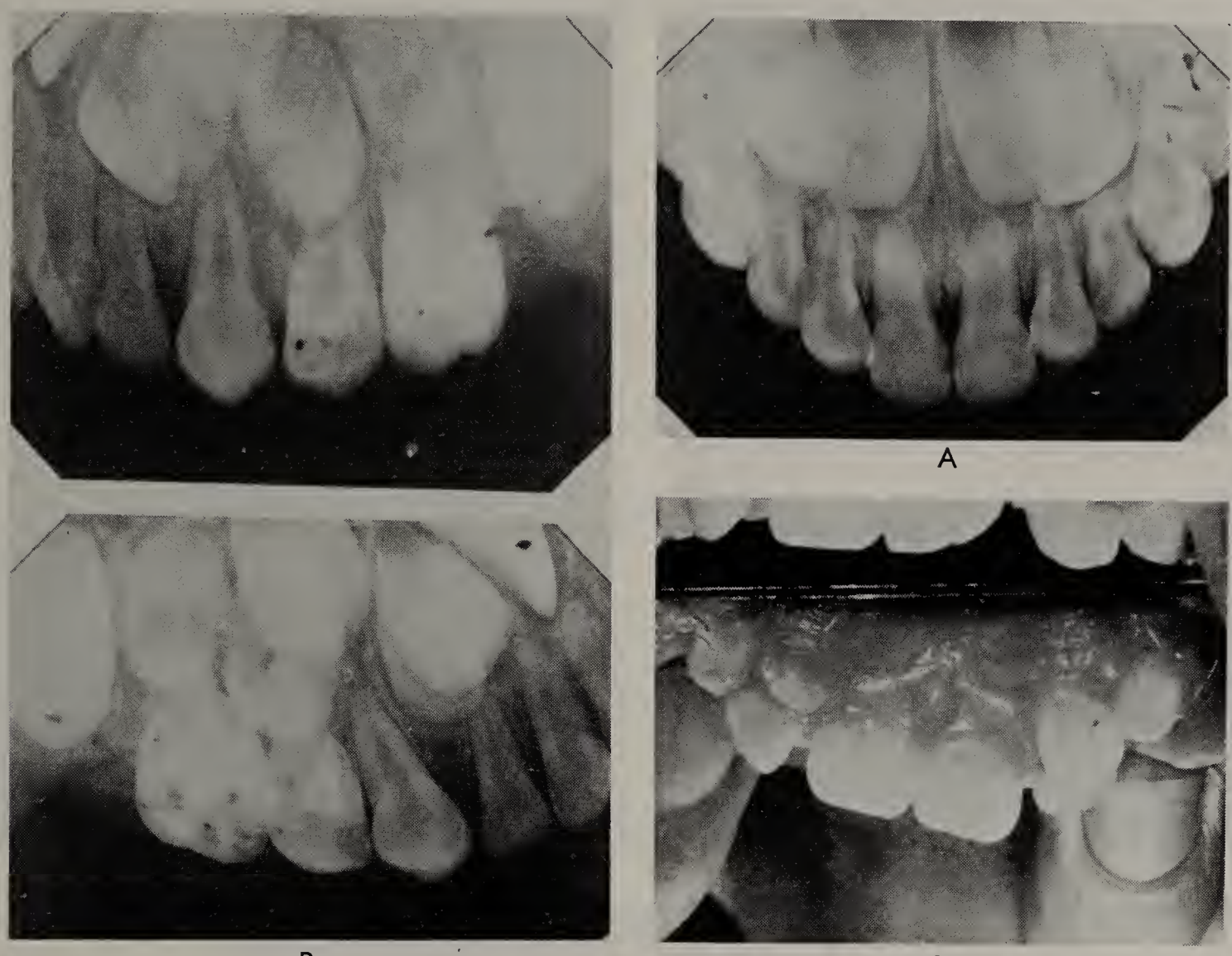


Fig. 4.—*Case* 4. A and B, Radiographs showing erupted primary and unerupted permanent supernumerary lateral incisors. C, Palatal eruption of supplemental lateral incisors.

CASE REPORTS

Case 1

The patient, a boy aged 6 years and 2 months, presented with primary supernumerary lateral incisors. *Fig*. 1A shows the supernumerary teeth to be a similar shape to the erupted primary lateral incisors and they can therefore be classified as supplemental teeth. Radiographs (*Fig*. 1B) taken at this time showed further supernumerary teeth superimposed over the unerupted permanent central incisors. A radiograph (*Fig*. 1C) taken at 10 years showed these two supernumerary teeth about to erupt between the erupted permanent central and lateral incisors. Following their eruption these teeth resembled the erupted lateral incisors and were supplemental in type. The supernumerary teeth in the permanent dentition were removed and the remaining incisors were alined.

Case 2

A girl, aged 4 years 2 months, was referred because of an erupted primary supernumerary upper left lateral incisor. A radiograph (*Fig*. 2A) showed the erupted supplemental lateral incisor and the crown of an unerupted supernumerary tooth forming adjacent to the permanent lateral incisor. Contact was lost with the patient and therefore no treatment was carried out at this stage.

The girl was again referred when aged 7 years and 3 months. This time her parents were worried because of an apparent delay in eruption of the permanent left central incisor.

A radiograph (*Fig*. 2B) revealed the conical-shaped crown of a supernumerary tooth developing distal to the permanent lateral incisor. The supernumerary and retained primary teeth were removed and the upper left central incisor erupted subsequently.

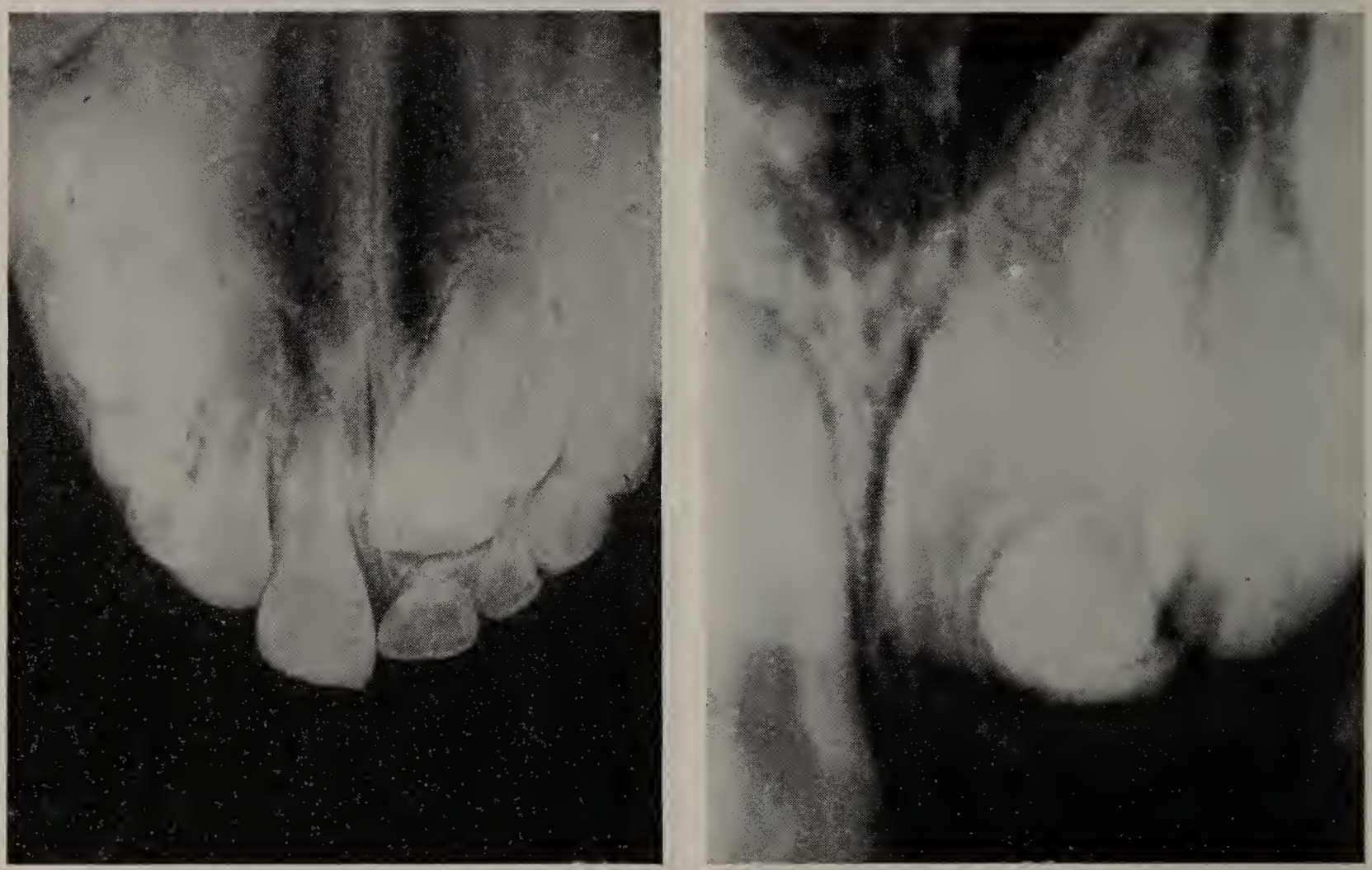
Case 3

A girl, aged 19 months, had an erupted supplemental tooth between $\underline{A|A}$. A radiograph (*Fig*. 3A) showed both the erupted primary supplemental tooth and a developing permanent supernumerary tooth. The primary supplemental tooth was extracted.

The patient was next seen when aged 9 years and 9 months and was referred because of delayed eruption of the upper right central incisor (*Fig*. 3B). An occlusal radiograph (*Fig*. 3C) confirmed the presence of the central incisor but showed its path of eruption to be blocked by a supernumerary tooth. Following the removal of the supernumerary tooth it was found to be a supplemental central incisor.

Case 4

A girl, aged 4 years 10 months, presented with erupted primary supplemental lateral incisors. Radiographs (*Fig.* 4A, B) revealed bilateral supernumerary teeth developing adjacent to the permanent lateral incisors. No treatment was carried out until the patient was 8 years old, when the erupted supplemental lateral incisors were removed (*Fig.* 4C).



A B

Fig. 5.—*Case* 5. A, Occlusal radiograph showing geminated $\underline{|AA}$ and supernumerary tooth superimposed over unerupted $\underline{|1}$. B, Unerupted $\underline{|1}$ and associated supernumerary.

Case 5

A boy, aged 9 years 9 months, presented with delayed eruption of the permanent upper left central and lateral incisors. The primary lateral incisor was retained together with a geminated primary central incisor. A radiograph (*Fig.* 5A) showed both the extent of the gemination and also the presence of a supernumerary tooth overlying the unerupted left central incisor (*Fig.* 5B). The geminated central incisor and the primary lateral incisor were extracted and the unerupted supernumerary was removed surgically. Eruption of the delayed incisors occurred rapidly without further treatment.

The supernumerary tooth was conical in shape and showed little evidence of any root formation. Following their eruption both the permanent upper left central and lateral incisors were of normal shape and size.

DISCUSSION

Table I summarizes the main features of the 11 new patients reported in this paper. Details of the patients previously described by other authors are contained in *Table II.* These details have been combined and examined to reveal the characteristics of supernumerary teeth occurring in both the primary and permanent dentitions.

The sex distribution of the patients in *Tables I* and *II* (13 males and 6 females) is consistent with the usual finding of a greater number of supernumerary teeth in males. Lind (1959) reports a 2 : 1 ratio of males to females for supernumerary teeth.

In the primary dentition 18 erupted supplemental upper lateral incisors were recorded in 14 patients, and 11 of these patients had 13 supplemental upper lateral incisors in the permanent dentition. Five primary supplemental lateral incisors were thus not followed by permanent supplemental teeth, but in 3 instances a conical supernumerary was found on a radiograph of the patient and in another case insufficient calcification had occurred to be sure of the eventual shape. Therefore only 1 primary supplemental tooth was not followed by a secondary supernumerary of some type.

The patient previously reported by Munroe (1952) as having a primary supplemental tooth distal to the primary upper right canine and with a history of extraction of a similar tooth from the opposite side showed on the radiographs the presence of upper lateral supplemental incisors in the permanent dentition.

One patient had a single primary supplemental upper central incisor and this was followed by a permanent supplemental central incisor. The patient presenting with the geminated primary central incisor had a conical supernumerary in the permanent dentition.

It is interesting to speculate how this developmental anomaly arises. The atavistic theory suggests that supernumerary teeth represent a reversion to the dentition of ancestral creatures. Although this theory no longer enjoys widespread support the dental formula of the typical

Table I.—Summary of New Cases

Sex	Primary Dentition		Permanent Dentition	
	Position	Type	Position	Type
M.	$\underline{B^sA|A^sB}$	Supplemental lateral incisor	$\underline{2^s1|1^s2}$	Supplemental lateral incisor
F.	$\underline{|AB^s}$	Supplemental lateral incisor	Unerupted $\underline{|2^s}$	Conical crown on radiograph
F.	$\underline{A^s|A}$	Supplemental central incisor	Unerupted $\underline{1^s|1}$	Supplemental central incisor
F.	$\underline{B^sA|A^sB}$	Supplemental lateral incisor	$\underline{{}^s21|12^s}$	Supplemental lateral incisor
M.	$\underline{|AB^s}$	Supplemental lateral incisor	$\underline{|12^s}$	Supplemental lateral incisor
M.	$\underline{B^sA|}$	Supplemental lateral incisor	Unerupted $\underline{{}^s21|}$	Supplemental lateral incisor
M.	$\underline{B^sA|A^sB}$	Supplemental lateral incisor	Unerupted $\underline{2^s1|1^s2}$	Supplemental lateral incisor. $\underline{2|}$ crown appears conical on radiograph
M.	$\underline{|A^sB}$	Supplemental lateral incisor	Unerupted $\underline{|1^s2}$	Supplemental lateral incisor
M.	$\underline{|A^sB}$	Supplemental lateral incisor	Unerupted $\underline{|1^s2}$	Supplemental lateral incisor
M.	$\underline{|A^sB}$	Supplemental lateral incisor	Unerupted $\underline{|1^s2}$	Supplemental lateral incisor
M.	$\underline{|AA.B}$	Geminated central incisor	Unerupted $\underline{|1^s2}$	Conical crown on radiograph

Two patients had supplemental lower lateral incisors, the condition being bilateral in 1 case. All 3 primary supplemental teeth were followed by supplemental lower lateral incisors.

Analysis of *Tables I* and *II* confirms that supernumerary teeth may be present in both the primary and permanent dentitions of the same patient. The primary supernumerary teeth are commonly supplemental in type, and in this series of patients 24 primary supplemental teeth were followed by 19 permanent supplemental teeth in the corresponding region. No other dental anomalies were recorded in these patients, but it must be borne in mind that some of the patients were as yet too young to be certain that further anomalies may not become evident.

mammalian dentition $\frac{3413|3143}{3413|3143}$ begins to resemble a patient with supplemental incisors.

A more likely theory is that an extra tooth germ arises directly from the dental lamina and gives rise to a series of supplemental teeth. Development proceeds normally and a successional tooth arises lingual to the primary supplemental enamel organ. This theory offers the best explanation for supernumerary teeth of the same shape and size and showing the same degree of development as the adjacent normal teeth.

A third possible explanation is that the tooth germ may undergo dichotomy. If the split is equal, supplemental teeth are formed, and if it is unequal a normal tooth together with a diminutive

Table II.—Summary of Cases presented by Other Authors

Author	Sex	Primary Dentition		Permanent Dentition	
		Position	Type	Position	Type
Townend (1953)	M.	$\underline{B^{s}A\vert}$	Supplemental lateral incisor	Unerupted $\underline{2^{s}1\vert}$	Supplemental lateral incisor
	M.	$\underline{B^{s}A\vert}$	Supplemental lateral incisor	Unerupted $\underline{2^{s}1\vert}$	Supplemental lateral incisor
Templar Barritt (1942)	F.	$\underline{\vert A^{s}B}$	Supplemental lateral incisor	Unerupted $\underline{\vert 1^{s}2}$	Crown conical on radiograph
Duffy (1963)	F.	$\overline{\vert^{s}B}$	Supplemental lateral incisor	Unerupted $\overline{\vert 1^{s}2}$	Supplemental lateral incisor
Munroe (1952)	M.	$\underline{B^{s}A\vert A^{s}B}$	Supplemental lateral incisor	Unerupted $\underline{\vert 2^{s}}$	Insufficient calcification
	M.	Erupted distal to $\underline{C\vert}$— history of tooth distal to $\underline{\vert C}$	Supplemental canine	Unerupted $\underline{2^{s}1\vert 1^{s}2}$	Supplemental lateral incisor
Robertson (1962)	F.	$\overline{B^{s}1\vert 1^{s}B}$	Supplemental lateral incisor	Unerupted $\overline{2^{s}1\vert 1^{s}2}$	Supplemental lateral incisor
	M.	$\underline{\vert A^{s}B}$	Supplemental lateral incisor	Unerupted $\underline{\vert 1^{s}2}$	Supplemental lateral incisor

tooth is formed. This may possibly explain the formation of the conical type of supernumerary tooth.

Gemination may arise either as incomplete dichotomy of a tooth germ or from the fusion of a normal tooth germ with that of a supernumerary or adjacent tooth.

SUMMARY

Eleven patients with supernumerary teeth present in both the primary and permanent dentitions are presented and compared with 8 similar cases reported elsewhere. The results show that the maxillary lateral incisor region is most frequently affected and that the teeth are commonly supplemental in type.

Acknowledgements

I am grateful to Professor T. D. Foster for his help and for permission to publish details of patients under his care, and to Professor A. I. Darling for permission to present the fifth case.

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THE RELATION BETWEEN ORTHODONTIC SPRING FORCE AND SPACE CLOSURE

J. J. CRABB, B.D.S., F.D.S., D.Orth. R.C.S.

H. J. WILSON, M.Sc.Tech., Ph.D., F.R.I.C.

The Dental School, Birmingham University

THE application of spring force and subsequent tooth movement has been studied by many workers. The experiments of Schwartz (1932) suggested that the optimum force should not be greater than capillary blood-pressure. This is usually between 15 and 20 mm. Hg and is equivalent to a pressure of 20–26 g. per cm.^{2} root surface. Further, all forces should be measured and if kept within the suggested range should move teeth at about the rate of 1 mm. per month, although there is much individual variation.

Oppenheim (1942) suggested using light forces with frequent periods of rest, whilst Hemley (1955) stated that the force exerted should not be through a distance greater than the width of the periodontal ligament. The classic histological studies of Reitan (1956) are well known, and he suggested that whereas an initial force as low as 25 g. should be applied to adult teeth it was possible to increase this to 30–40 g. in younger patients. After this stage the force could be increased to a maximum of 100–150 g.

Until quite recently standard British textbooks were unanimous in recommending a pressure of 20–25 g. per cm.^{2} root surface, a figure in agreement with the findings of Schwartz (1932). Tulley and Campbell (1965) stated: ' Practically speaking a pressure of 20–25 g. can be applied to a single rooted tooth with a root area of approximately 1 sq. cm. ', but in their new revised edition (1970) they have discarded the description of root area, possibly influenced by the recent work of Bass and Stephens (1970). In their prize essay which was read before our Society, Bass and Stephens mentioned the difficulty of interpreting the original statement in the light of information provided by Kantorowitz (1963). The average root areas for maxillary canines was given as 2·665 cm.^{2} but there was no indication as to whether the roots were completely or incompletely formed. In the discussion following the paper by Bass and Stephens (1970) Tulley suggested that the relevant root area was the face of the tooth which was moving, that is, the projected root area. Walther (1967) suggested that for tipping movements a very light force should be applied initially and that this could be increased to about 50 g. for a single rooted tooth.

The difficulty of selecting the correct force to move a tooth was emphasized by Storey and Smith (1952), who found that bodily movement of mandibular canine teeth was achieved satisfactorily with forces as high as 135–300 g. Burstone (1962) also noted similar rates of tooth movement produced by different forces, but both these papers dealt with fixed appliances and their results must be applied with caution to removable appliances. Bien (1967) reported that the duration of a force applied was more important than the absolute magnitude of the force itself. However, his experiments were conducted on animals.

Adams (1970) found that in practice a force of 20 g. could be increased for larger teeth such as molars and canines, but although high pressures will produce tooth movement the rate may not be greater than with low pressures. Atherton (1964) calculated the rate at which teeth were moved distally by springs on removable appliances but ' made no attempt to correlate the tension applied to the speed of the tooth movement '. Using 0·55-mm. palatal springs on upper canines the force applied varied between 40 and 100 g. The mean rate of tooth movement was 0·0562 mm. per day. Such a rate suggests a movement of some 1·5 mm. per 28 days, which is somewhat higher than the more generally accepted rate of 1 mm. per month.

In their review of the literature Bass and Stephens (1970) concluded: ' It is evident, therefore, in the absence of any satisfactory experimental clinical study of the effect of forces applied by springs carried on removable appliances, that " clinical experience " is still the only guide.' Further they state that if one-third of the width of the tooth is taken as the correct degree of activation for a spring then the magnitude of the force will depend on which tooth is being moved. Horowitz and Hixon (1966) quote

Presented at a meeting held on March 8, 1971.

the mean mesiodistal diameter of maxillary canines as 7·8 mm., a figure in close agreement with our mean value of 7·7 mm.

The present investigation sets out to relate tooth movement to a force applied using one particular tooth (the upper canine), different force ranges, and a selected age-group. The forces were 0·3, 0·4, and 0·5 N. Upper removable appliances were fitted to all patients, and distal movement of the canines was achieved by using 0·5-mm. diameter, hard, stainless-steel wire from one reel (K. C. Smith and Co.) in the form of palatally approaching cantilever springs, as described by Adams (1970) and in other texts. All the springs were made using a spring-forming machine similar to that used by Bass and Stephens (1970). The diameter of the shank of the straight bur used as a spindle was 2·33 mm., producing springs with a coil of mean internal diameter 2·77 mm. Similar springs were made for the laboratory

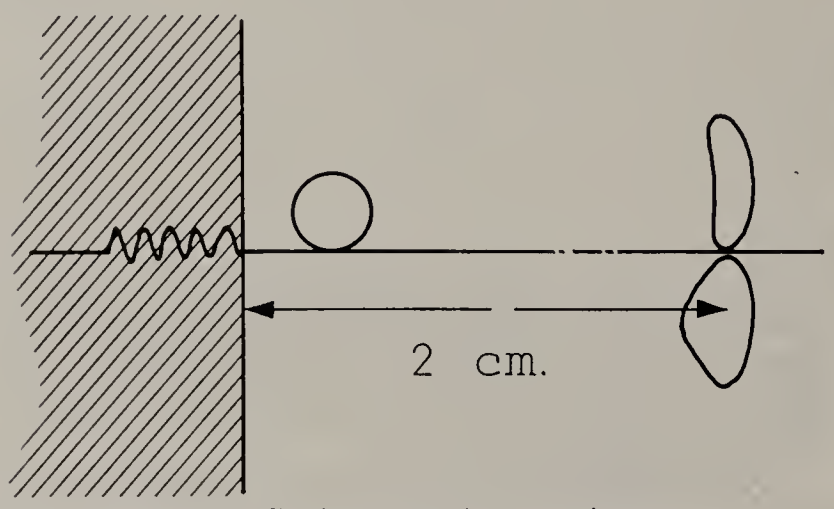


Fig. 1.—Spring used in experiments.

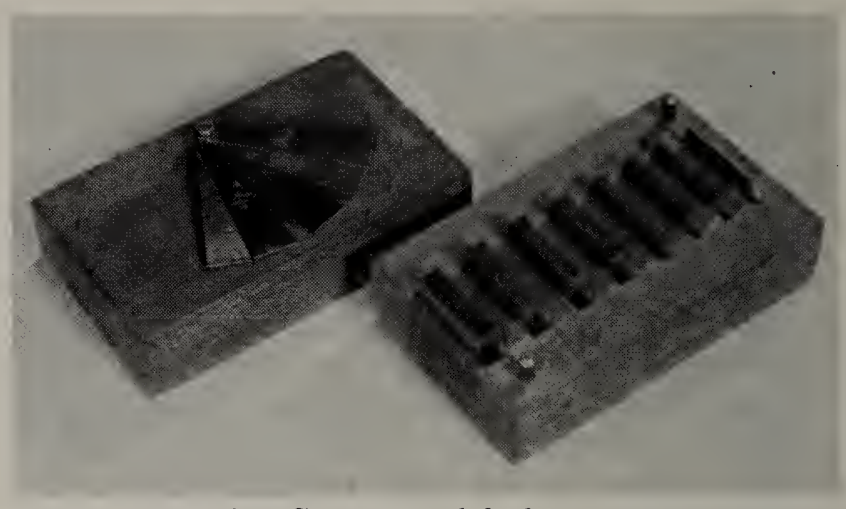


Fig. 2.—Spacer and feeler gauges.



Fig. 3.—Measurement of space between teeth.

measured in Newtons,* the Newton (N) being the unit of force in the S.I. (Systéme Internationale) system of units. Additionally, work was done in the laboratory to determine the relationship of spring force with deflexion.

MATERIALS AND METHODS

Twenty patients with a mean age of 11 years 9 months were selected from the orthodontic waiting list, each patient having a Class II, division 1 occlusion requiring treatment, with all upper premolars and canines fully erupted. As part of a common treatment plan, upper first premolars were extracted and distal movement of the upper canines was undertaken.

The patients were divided into three groups and a different force was used on each group:

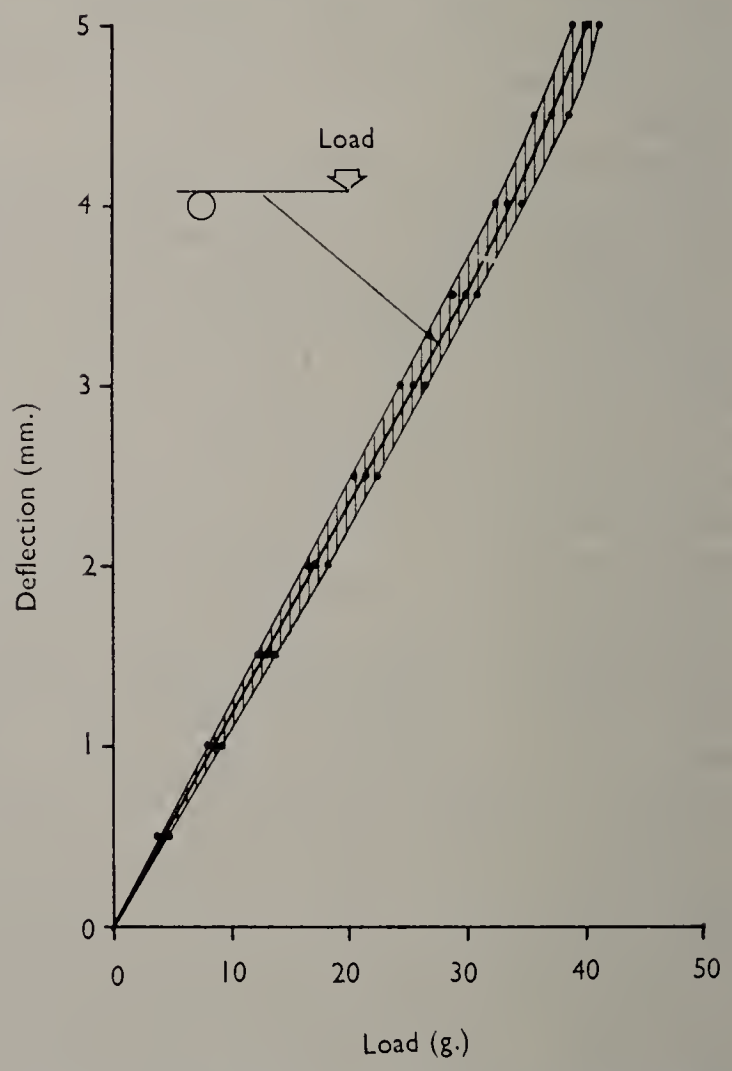


Fig. 4.—Variation of load with deflexion for a 2 cm. long spring of 0·5 mm. diameter containing a coil of internal diameter 2·77 mm. The outer lines refer to one standard deviation.

*1 Newton is equivalent to approximately 100 g.

experiments. Care was taken to ensure that after formation of the coil the two straight limbs were in line. The length of the spring for each patient was 2 cm. (*Fig.* 1) and all canines were easily accessible to the springs

Retention of the appliance depended on Adams clasps on the first molars, accessory clasps on the second premolars, and a double clasp on the central incisors. A flat anterior bite platform served to reduce the overbite and to prevent occlusal interference from the posterior teeth. Patients were fitted with their appliances before extractions to avoid drifting of teeth, and activation of the springs was performed at the next visit. It was not possible to maintain a constant time interval between extractions and activation.

The amount of space closure between the upper canines and the second premolars at each visit was measured using standard spacer and feeler gauges, as shown in *Fig.* 2. Measurement of the forces applied initially and at the second and subsequent visits was made using a force-measuring probe. This was constructed of stainless steel, onto which was cemented two silicon strain gauges, one on either side of a reduced section to compensate for temperature changes. The gauges formed part of a Wheatstone-bridge circuit, the output from which was related to the force applied to the end of the probe. This output was recorded on a ultra-violet recorder. Calibration of the probe by static loading indicated that the output was linear over the range used.

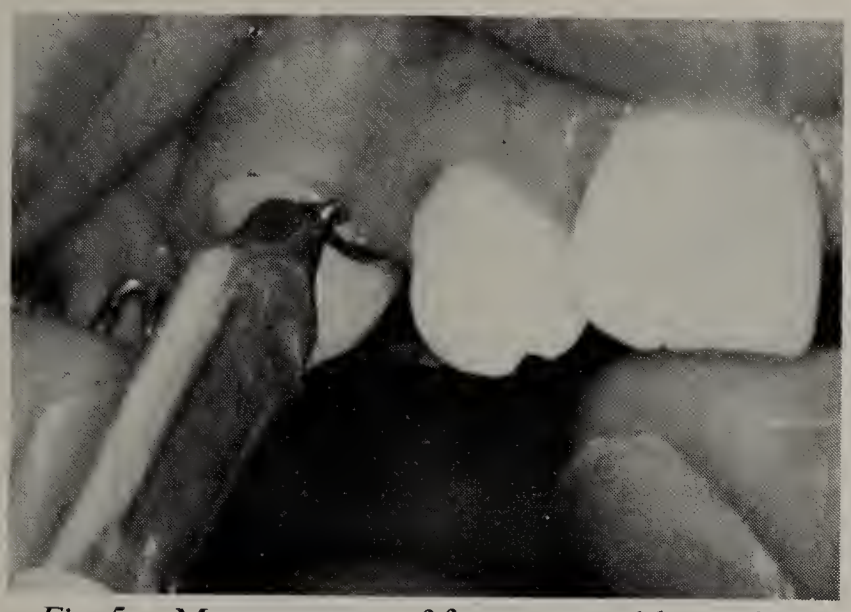


Fig. 5.—Measurement of force exerted by spring.

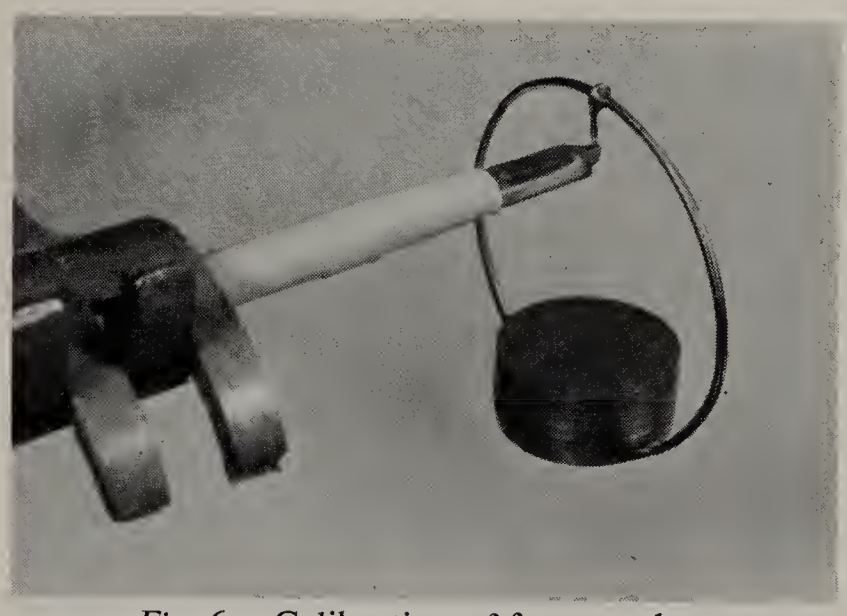


Fig. 6.—Calibration of force probe.

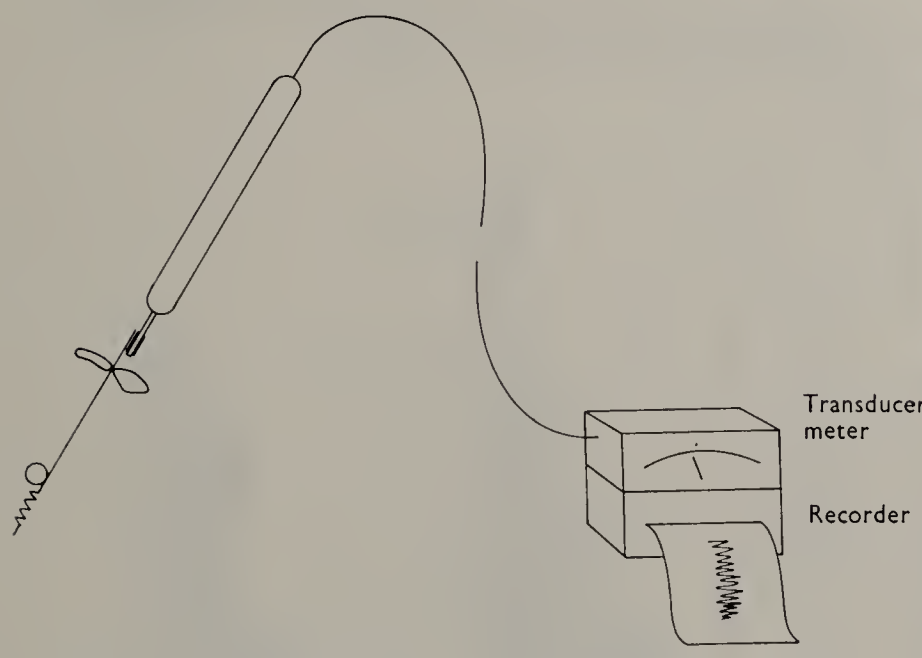


Fig. 7.—Diagrammatic representation of probe, transducer meter, and ultra-violet recorder.

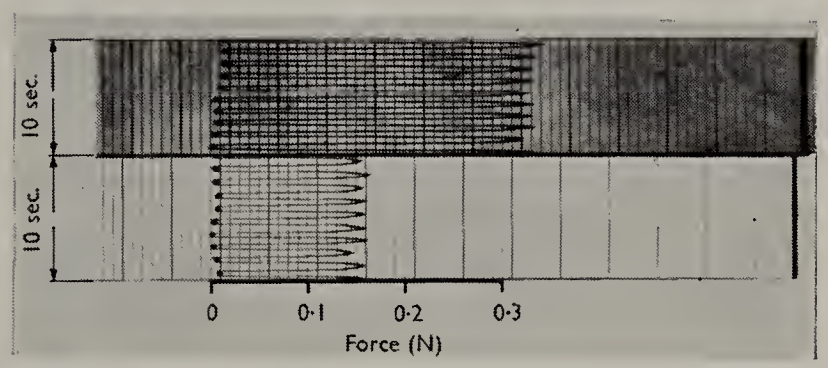


Fig. 8.—Typical traces obtained showing original activation force above and residual force below.

An alternative method of measuring spring force is by the use of a Correx gauge* with a range of 0–50 g. The accuracy of this gauge was established by static loading and was found to read 5 per cent below the true reading.

At the first visit following the extractions the spaces between the canines and premolars were measured (*Fig.* 3) and the springs were then activated until the required force was exerted. In practice it was obviously impossible to produce a force of exactly 0·3, 0·4, or 0·5 N, and a tolerance of $\pm$0·02 N was accepted. In order to give some indication of the amount of deflexion necessary the variation of load with deflexion was compiled. This was obtained when a spring 2 cm. long was progressively loaded to a maximum deflexion of 5 mm. (*Fig.* 4). The values obtained are in close agreement with those obtained by Bass and Stephens (1970).

*Supplied by James W. Carr & Co. Ltd., London.

The force on the canines was measured after minimal deflexion of the free end of the spring mesially by the probe (*Fig.* 5). When the probe was subjected to load, one strain gauge was in compression and the other was in tension so that the output was doubled. The change in resistance of the strain gauges was proportional to the load applied and therefore the probe was calibrated by static loading, as shown in *Fig.* 6. The output from the transducer meter was fed into an ultra-violet recorder, as shown diagrammatically in *Fig.* 7. The type of result obtained is illustrated in *Fig.* 8.

With some patients the close proximity of the lateral incisors to the canines made it impossible to measure the force exerted by the spring in the mouth. This was, therefore, performed using the original working model, as shown in *Fig.* 9.

Patients were instructed in the careful handling of the appliance and were asked to note the day an accident such as a broken spring occurred or the appliance was left out for any reason.

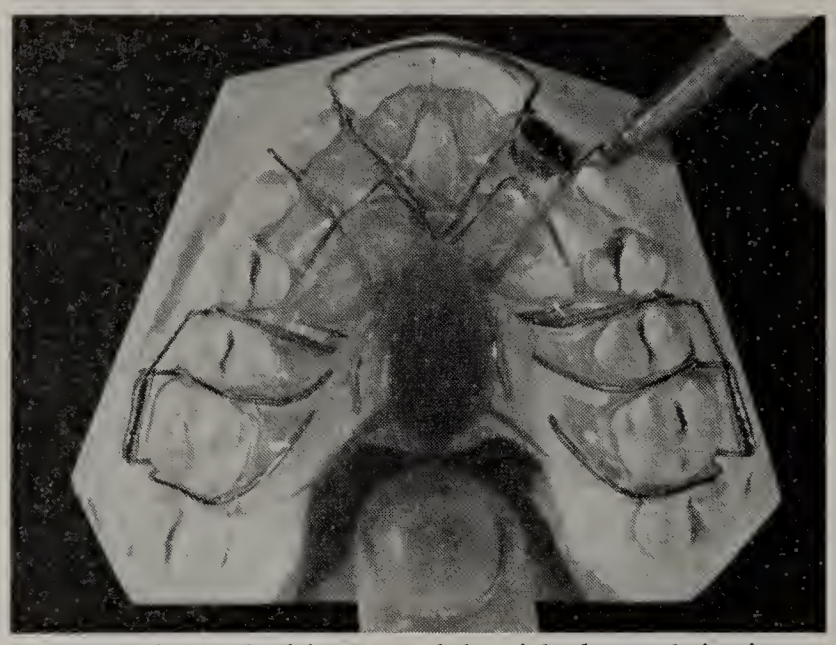


Fig. 9.—Working model with lateral incisor removed used to measure force exerted by spring when a lateral incisor and canine were in close proximity.

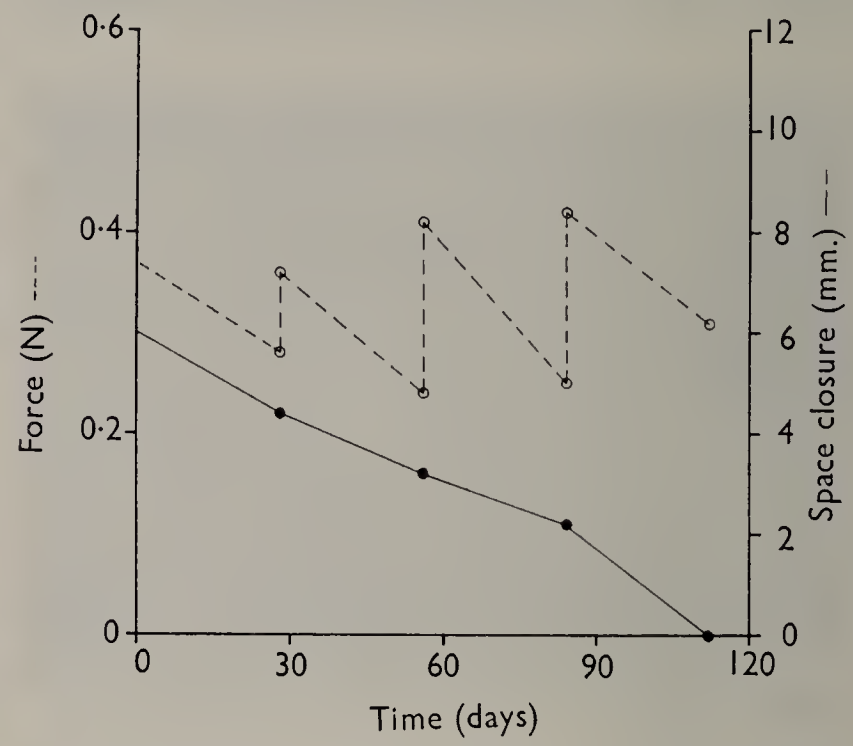


Fig. 10.—Variation of spring force and space closure with time for the left side of a female aged 12 years.

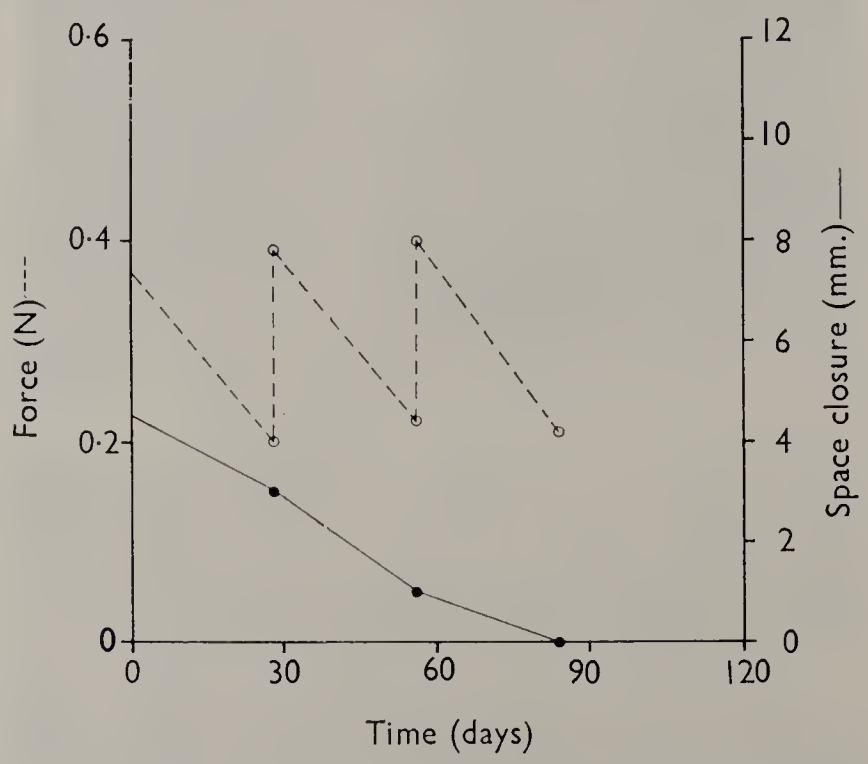


Fig. 11.—Variation of spring force and space closure with time for the right side of the same patient as in *Fig.* 10.

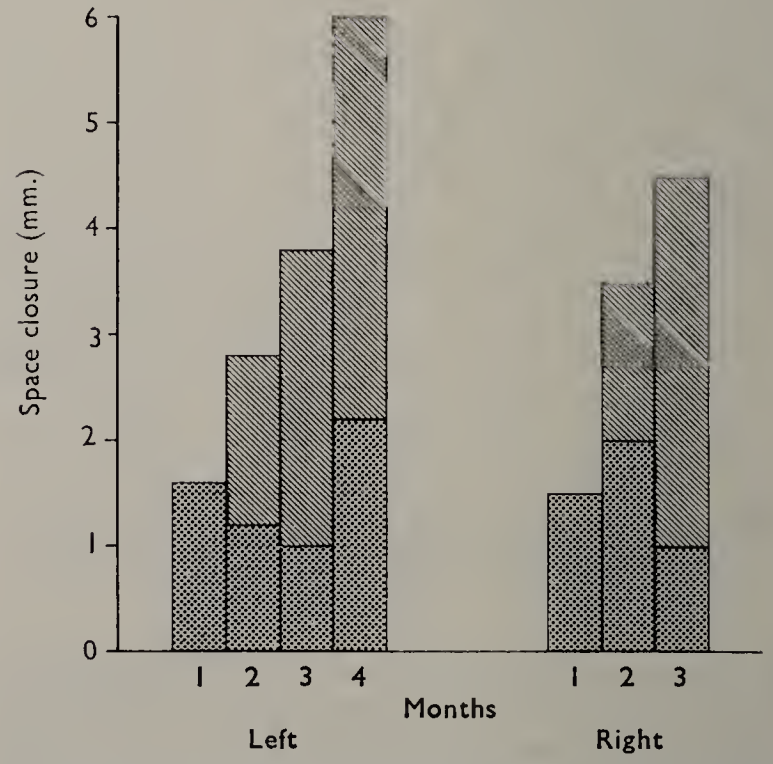


Fig. 12.—Space closure per month (lower bars) and total space closure for the same patient as in *Fig.* 10.

At the second visit, notes were made of the space closure, the residual forces exerted by the springs, and the new forces produced by further activation to the original range. Every effort was made to see the patients every 28 days, but this was not always possible. In one or two instances activation was delayed until this was possible. Note was made of distortions, fractures, or failure to wear appliances.

RESULTS

A typical result is shown in *Fig.* 10, which is of the left side of a patient in the 0·4 N group. The left vertical ordinate indicates the force and the horizontal ordinate the time. The peaks indicate the first force applied and the reactivated forces shown in *Fig.* 11 which indicates a similar pattern. This time, however, the space closure after extractions and before activation of the springs, had been greater, and active treatment was required for 84 days to close a space of 4·5 mm., again achieving a mean rate of tooth movement

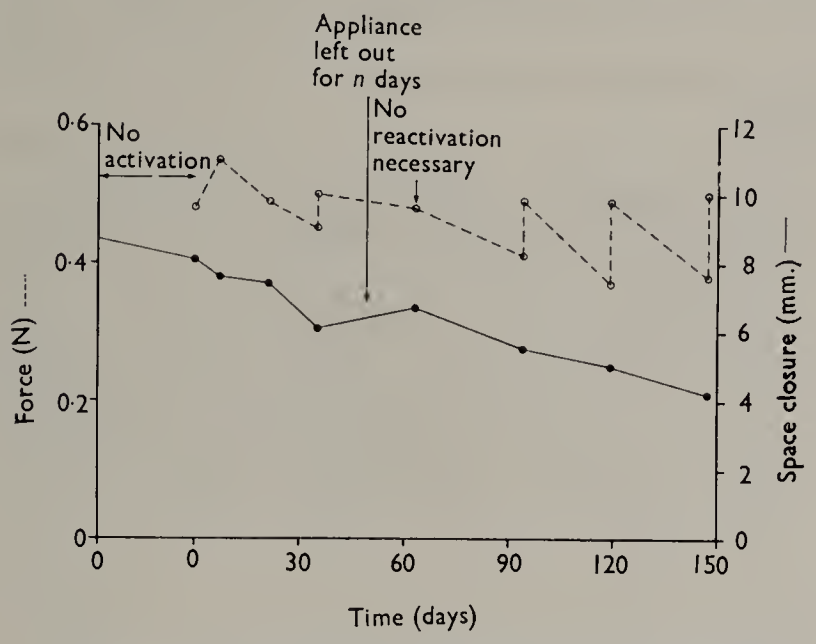


Fig. 13.—Variation of spring force and space closure with time for the left side of a male aged 14 years 3 months.

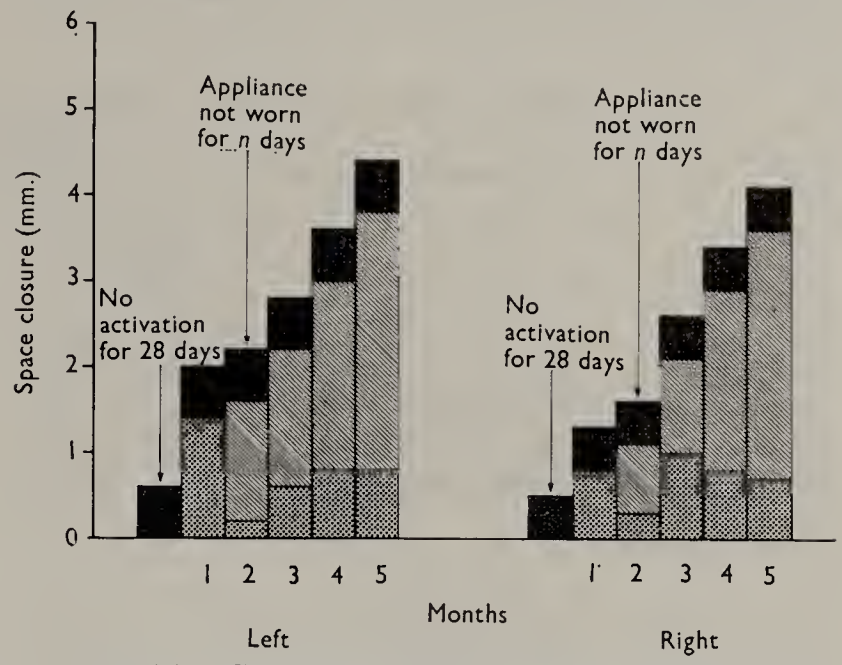


Fig. 14.—Space closure per month (lower bars) and total space closure for the same patient as in *Fig.* 13.

Table I.—Mean Rate of Tooth Movement per 28 Days for an Activation Force of 0·3 N

Patient	Total Time taken (days)		Space Closure (mm.)		Rate (mm. per 28 days)	
	Left	Right	Left	Right	Left	Right
P.E., male	189	189	5·2	5·6	0·8	0·8
			Mean (male)		0·8	0·8
S.B., female	140	140	4·3	5·1	0·9	1·0
S.C., female	183	155	4·9	5·9	0·7	1·1
D.M., female	127	127	6·5	6·7	1·4	1·5
K.W., female	82	82	3·9	3·7	1·3	1·3
D.W., female	183	155	6·1	6·5	0·9	1·0
				Mean (female)	1·0	1·4
				Overall mean (male+female)	0·9	1·1

at each visit, whilst the lower points show the residual forces. The right vertical ordinate indicates the amount of tooth movement. The patient wore the appliance faithfully, removed and inserted it correctly, did not damage it, and could attend every 28 days, in short, a model patient. The total treatment time needed to close a 6-mm. space was 112 days, giving a mean rate of tooth movement of 1·5 mm. per 28 days. Results for the right side of the same patient are of 1·5 mm. per 28 days. *Fig.* 12 shows results from both sides of the same patient and indicates the space closure every 28 days and the total amount of space closure for successive months.

Fig. 13 shows an atypical result in the 0·5 N group. No activation could be performed at the first visit following the extractions. The patient returned at the third visit with the left spring distorted so that the force was increased, and later the appliance was left out for an unspecified

number of days, resulting in a reopening of the space. Needless to say no reactivation of the spring was necessary. The erratic rate of space closure per 28 days is shown in *Fig.* 14, and since the patient could not attend every 28 days results were obtained by extrapolation from the graph. The time taken to close 3·9 mm. was 147 days, that is, a mean rate of tooth movement of 0·7 mm. per 28 days. *Tables I, II,* and *III* show the mean rate of tooth movement per 28 days for individual patients. One patient (S.C.) fractured the left spring for a period, which explains the low reading. Such patients have been included in the results, after some thought, since

Table II.—Mean Rate of Tooth Movement per 28 Days for an Activation Force of 0·4 N

Patient	Total Time taken (days)		Space Closure (mm.)		Rate (mm. per 28 days)	
	Left	Right	Left	Right	Left	Right
C.L., male	144	148	5·0	7·0	1·0	1·3
A.M., male	168	168	6·0	4·6	1·0	0·8
				Mean (male)	1·0	1·1
A.C., female	112	84	6·0	4·5	1·5	1·5
I.F., female	168	168	5·0	5·4	0·8	0·9
S.G., female	229	203	6·9	7·4	0·8	1·0
J.P., female	168	168	7·2	7·2	1·2	1·2
L.T., female	49	49	3·2	2·7	1·8	1·5
				Mean (female)	1·2	1·2
				Overall mean (male+female)	1·1	1·2

Table III.—Mean Rate of Tooth Movement per 28 Days for an Activation Force of 0·5 N

Patient	Total Time taken (days)		Space Closure (mm.)		Rate (mm. per 28 days)	
	Left	Right	Left	Right	Left	Right
I.F., male	147	119	3·9	3·8	0·7	0·9
D.P., male	158	158	7·3	9·0	1·3	1·6
P.S., male	126	126	4·9	4·7	1·1	1·0
				Mean (male)	1·0	1·2
G.H., female	147	147	3·7	3·7	0·7	0·7
J.L., female	133	133	4·3	5·9	0·9	1·2
C.M., female	85	83	4·2	6·3	1·4	2·1
K.P., female	112	112	6·7	6·6	1·7	1·7
				Mean (female)	1·2	1·4
				Overall mean (male+female)	1·1	1·3

this is what can happen in practice with the problems in patient co-operation and appliance management. Thus, final readings are probably on the low side. The results of the 0·4 N and 0·5 N groups did not differ significantly from those of the 0·3 N group. In fact, there was remarkable similarity. *Table IV* shows the overall mean rate of tooth movement for 28 days for different forces.

DISCUSSION

In any clinical experiments there are problems relating to the patient and his appliance, and there is little doubt that the length of treatment is to a large extent dependent on patient co-operation. Boys appear to be more of a problem than girls. For example, one boy (P.E.) fractured the left spring three times and the anterior double crib once. These misfortunes probably explain

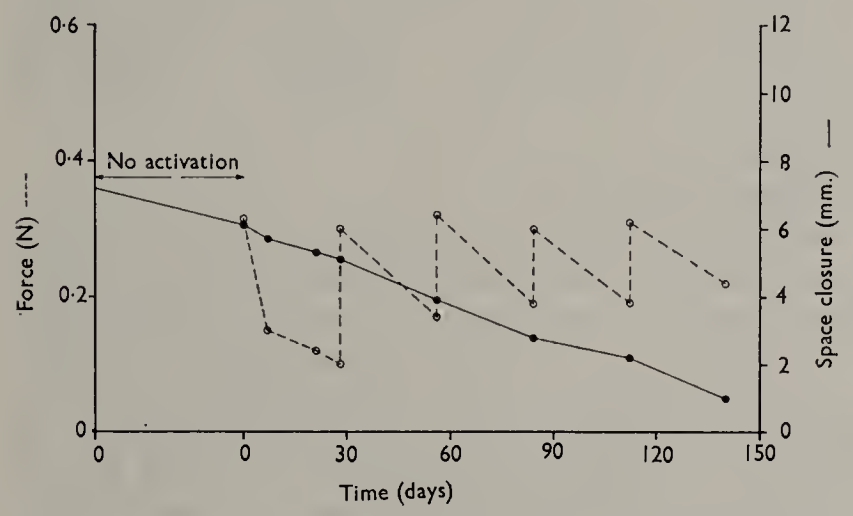


Fig. 15.—Variation of spring force and space closure with time when the spring was not activated for 43 days for the right side of a female aged 13 years 2 months.

given a larger number of patients. Inspection of *Table IV* indicates that the rate of space closure is not influenced, to any significant extent, by the force of the spring, the sex of the patient, or the side of the mouth.

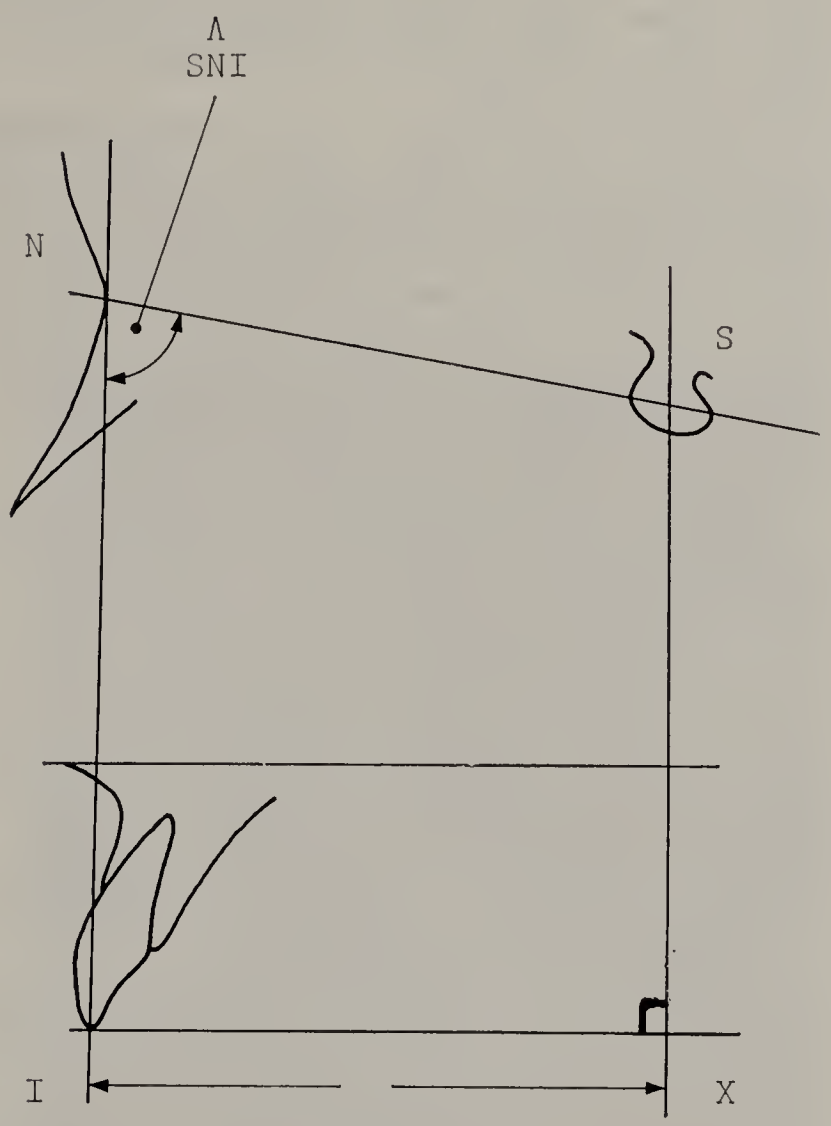


Fig. 16.—Method of obtaining angular and linear measurements from lateral skull tracings.

Table IV.—Mean Rate of Tooth Movement per 28 days for Different Activation Forces

Sex of Subjects	Activation Force					
	0·3 N		0·4 N		0·5 N	
	Left	Right	Left	Right	Left	Right
Male	0·8	0·8	1·0	1·1	1·0	1·2
Female	1·0	1·4	1·2	1·2	1·2	1·4
Male+female	0·9	1·1	1·1	1·2	1·1	1·3
Mean (left+ right sides)	1·0		1·1		1·2	

the relatively low mean rate of tooth movement of 0·8 mm. per 28 days. However, these experiments were performed on only 20 patients divided into three groups and the results recorded may only be pointers to what might well be true

The method would seem to have great potential and be economically feasible if a Correx gauge was used in place of the probe. For large numbers of patients the gauge would save considerable time but would have to be calibrated frequently.

This work could be extended to find, for example, how long a spring could be left activated before tooth movement ceased, in other words what is the best time interval for activation purposes. No work has yet been done using 0·1 N or 0·2 N forces. There is probably some critical force range below which tooth movement does not occur. Bass and Stephens (1970) suggest this is about 8–10 g. (0·1 N).

Problems with appliances tended to be confined to the 0·5 N group. Three patients complained of pain around the canine teeth during the first 24 hours and most found it difficult to insert the appliance with the spring on the mesial side of the canines. In 2 instances the spring was found to be on the wrong side at the next visit and the space had increased rather than decreased. It was more difficult to produce the correct force in this group than in the other two. It was purely a clinical impression that the canines tilted appreciably in the 0·5 N group, but this was not measured either before or after treatment.

One interesting feature was the amount of tooth movement which took place spontaneously once extractions had been done. In the cases where this was allowed to occur (*Fig.* 15) the rate was similar to that produced by spring force. This suggests that the patient need not be seen too early after the extractions, where the springs of the appliance are passive.

The problem of loss of anchorage was considered throughout the experiments. This is why space closure has been considered and not specific tooth movements. Loss of anchorage may well occur, particularly in the 0·5 N group, and therefore lateral skull radiographs were taken of the majority of the patients and were traced before and at the end of the experiments for comparison. Two measurements were taken, the SNI angle and a linear measurement I–X (*Fig.* 16). No significant difference was observed in the readings before and after treatment. Growth changes may influence the second readings and therefore the measurements which were taken have their limitations.

The results shown diagrammatically in *Fig.* 4 are similar to those produced by Bass and Stephens (1970) and give a good guide as to the amount of force that is produced for a given deflexion. Further work is proceeding using coils the wrong way round, coils of different diameter, and wires of various thicknesses.

SUMMARY

A reliable method has been described to measure orthodontic forces applied by springs. Twenty patients were divided into three groups. A known force range was applied to the upper canines and the space closure was measured at each visit. Graphs were plotted and from these the rate of space closure per 28 days was calculated. The rates of space closure within each group were not related to sex or to side of the mouth, and there was no significant difference in rate between the three groups. There appears to be a fairly wide force range within which space closure will occur at equal rates, all other factors being favourable. However, despite the similar rates of space closure for different activation forces there were problems of appliance management and tooth movement in the higher force group. When the activation force was 0·5 N pain was experienced initially in 3 patients, appliances tended to be inserted with the spring being displaced to the distal side, and there seemed to be much tilting distally of the upper canines. Tracings made from lateral skull radiographs indicated that there was no significant anchorage loss in any of the three groups. Load/deflexion tables for standard springs are a guide as to how much deflexion is needed to produce a certain load.

Acknowledgements

We would like to thank Professor Foster for his encouragement and advice, Mr. I. H. Jones for invaluable technical assistance, Messrs. Bass and Stephens for a pre-publication copy of their paper, and Mr. A. G. Huddart for his suggestion of a linear measurement in assessing loss of anchorage. We would also like to thank Mr. P. Jones for his help in laboratory tests and Mr. R. Frazier and his staff for the illustrations.

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THE UNERUPTED CANINE

J. P. MOSS, B.D.S., F.D.S., D.Orth.

University College Hospital Dental School, London

THE maxillary canine is one of the most frequently misplaced teeth in the dental arch and is second only to the third molar in frequency of impaction (Thoma, 1958). When lying in an unfavourable position it is a difficult problem for the orthodontist, especially as it is often associated with some loss of space, an aesthetically poor deciduous canine, and a patient who does not want prolonged treatment. Rohrer (1929), Mead (1930), Bass (1967) stated the incidence of this type of problem to be between 1·5 and 2 per cent of all orthodontic cases. Bass (1967) also investigated the time required for treatment and showed that in 90 per cent of the cases surgery was required and the duration of orthodontic treatment was from 9 to 21 months. As this is a common and often difficult problem where the patient requests minimal treatment, a combined surgical and orthodontic approach has been advocated.

In the present paper the normal development of the canine and the causes of non-eruption of this tooth will be briefly considered. The assessment of the canine and methods of treatment with special reference to transplantation will then be discussed.

THE NORMAL DEVELOPMENT OF THE CANINE

Before consideration is given to the abnormal position of the canine the effects of the normal eruption of this tooth on the arch should be considered. The normal development of the canine has been admirably described by Broadbent (1941). The upper canine commences calcification at about 4–12 months after birth, the crown being completed at approximately 6–7 years. The tooth develops high in the fronto-nasal process of the maxilla near the inferior border of the orbit. The position of the tooth at this early stage is above the roots of the first deciduous molar and is distal to the developing lateral incisor tooth which does not usually calcify until later.

The growth of the face and jaws carries the deciduous teeth downwards and forwards, making further space for the developing permanent teeth. The canine remains high in the maxilla just above and distal to the lateral incisor and does not seem to move from this position until the crown is fully calcified. The close proximity of the canine to the lateral incisor root causes the typical

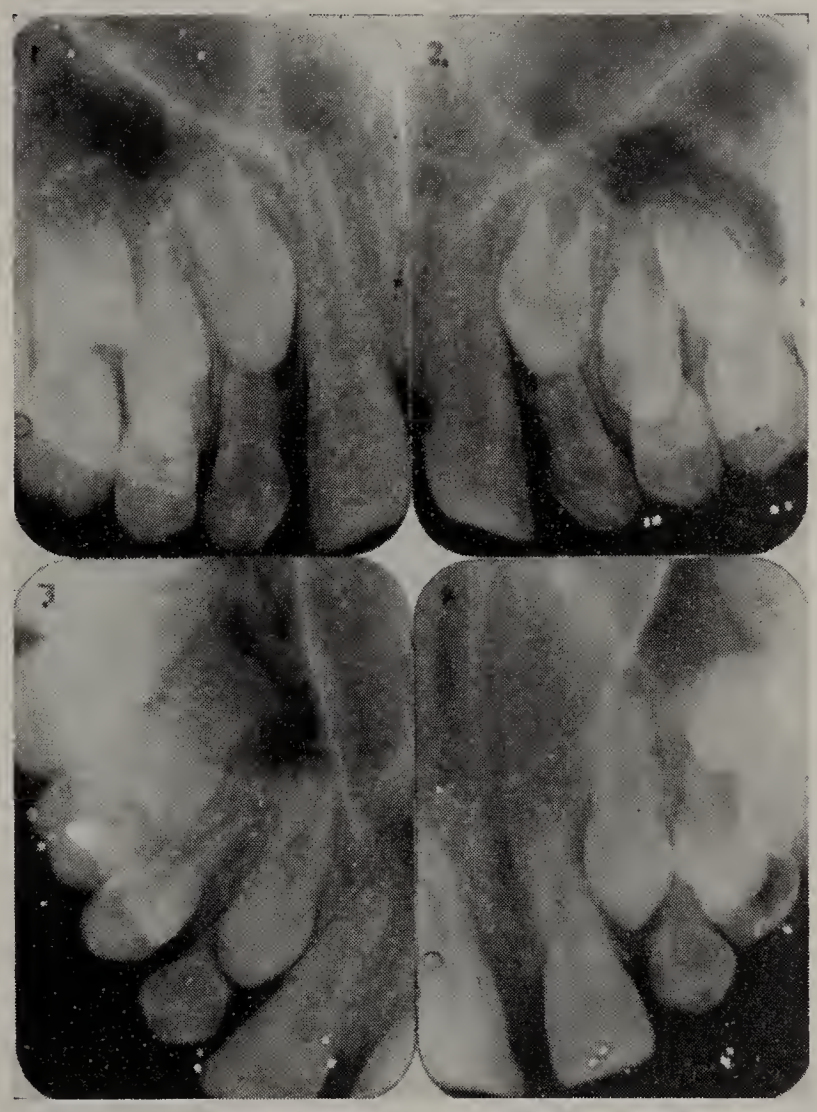


Fig. 1.—*Case* C.B. The position of the unerupted canines at 8 years (*above*) and at 10 years (*below*) in a patient in whom the upper lateral incisors are congenitally missing. Notice how the canine has erupted mesially into the lateral incisor space.

movement of this incisor tooth during the eruption of the upper canine. With normal development of the maxilla the canine travels along the distal aspect of the root of the lateral incisor, resulting in closure of the physiological diastema if it is present. The importance of the lateral incisor as a guide to the normal eruption of the canine is seen when the lateral incisors are absent and the canine erupts mesially into the lateral incisor space (*Fig.* 1). Root formation is usually complete within 2 years of eruption, but unlike

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other teeth almost three-quarters of the root of the canine is complete before eruption into the mouth commences.

WHY DO CANINES BECOME DISPLACED?

The frequent displacement of the canine is probably due to its high developmental position and the advanced state of development of the

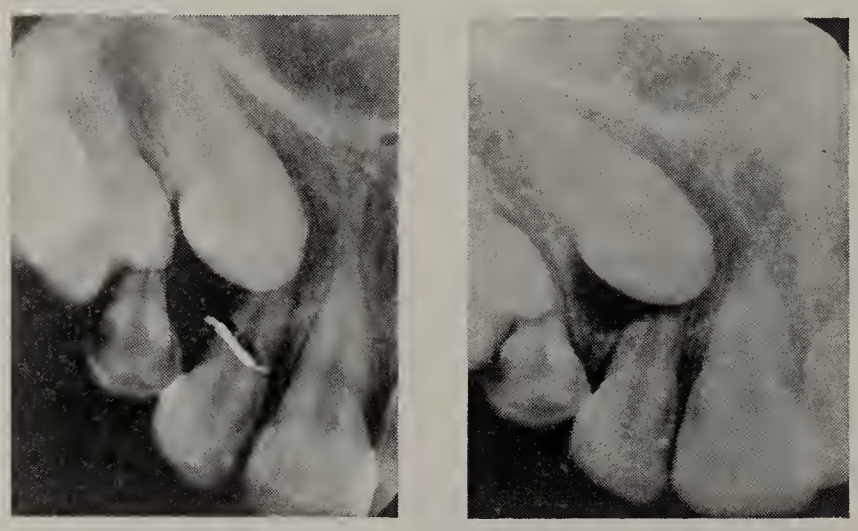


Fig. 2.—*Case* S.L. The intra-oral film on the left was taken 9 months before the patient complained of mobility of the upper lateral incisor. During the 9 months considerable resorption of the $\underline{2}|$ had taken place, as is shown in the intra-oral film on the right.

Retained deciduous teeth are sometimes suggested as possible causes of non-eruption, but in some cases failure of resorption of the deciduous tooth may be due to the canine being displaced, resulting in an abnormal path of eruption.

ASSESSMENT OF THE CANINE

Before advice on the treatment of the canine can be given the unerupted canine must be assessed clinically and radiographically. During the clinical examination the following points must be assessed.

The Amount of Space in the Arch for the Unerupted Canine

Observation of the mouth will enable the operator to determine whether there is sufficient space in the arch for the unerupted tooth. If there is inadequate space, consideration must be given to reopening the space or allowing it to close following the extraction of the canine.

The Morphology and Position of the Adjacent Teeth

A careful examination of the morphology of the premolar and its angulation and rotation

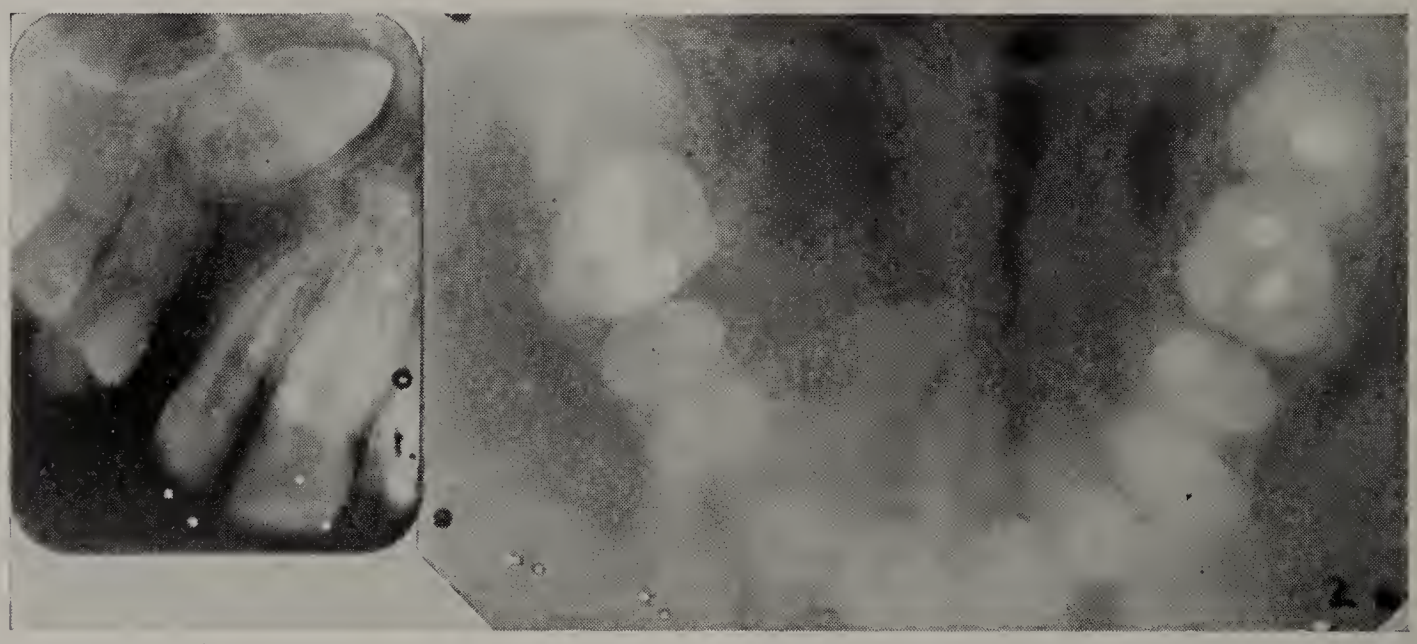


Fig. 3.—*Case* M.R. Intra-oral and vertex occlusal views of the $\underline{3}|$ taken for the location of the unerupted tooth.

crown at an early age. At this stage it is dependent on normal growth of the maxilla allowing it to move into its correct position, and Broadbent (1941) showed the importance of the amount and direction of growth for the normal eruption of the teeth. The correct position of the adjacent teeth to guide the canine into its right location is also important.

Apart from displacement of the tooth from its normal developmental position, generalized non-eruption of teeth in such conditions as cleidocranial dysostosis and local causes of non-eruption such as cysts, odontomes, and tumours may prevent the normal eruption of the canine.

must be undertaken, especially if extraction of the canine is contemplated. A mesiolabially rotated premolar can be aesthetically undesirable. If there is a short upper lip present, consideration must also be given to the height of the gingival margin, which is lower on premolars than on canines.

The position of the lateral incisor tooth is a valuable indication of the position of the unerupted canine. The canine often presses on the root of the lateral incisor tooth, resulting in displacement of the crown. A distally inclined incisor indicates that the canine is in close proximity to the distal part of the apex of the

lateral incisor tooth. Similarly, a labially inclined lateral incisor tooth indicates that the canine is labial to the root of the lateral incisor.

The Contours of the Bone

Palpation and comparison of the contours of the alveolar and palatal bone of both sides often reveals the position of the unerupted canine tooth.

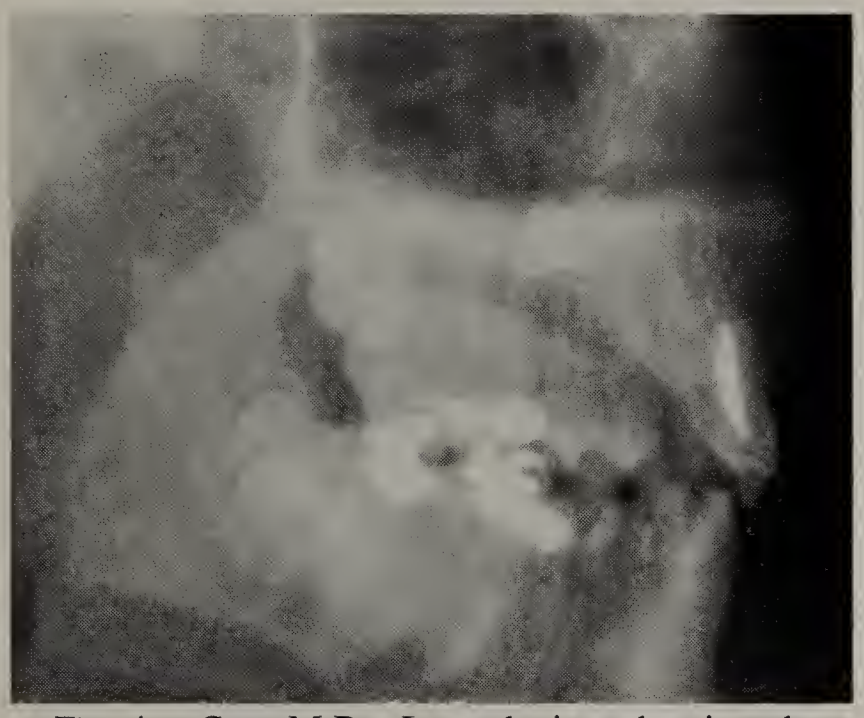


Fig. 4.—*Case* M.R. Lateral view showing the position of the canine on the floor of the nose.

If it lies buccally the height of the tooth relative to the adjacent structures such as the floor of the nose should be assessed.

The Mobility of the Teeth

The teeth should be examined for mobility, especially the deciduous canines and the lateral and central incisors, as resorption of these teeth may have occurred (*Fig*. 2).

Radiographic Examination

Many different radiographic views have been suggested in order to locate the maxillary canine accurately. The main problem is that the canine is often partly in the alveolus and partly in the palate and the adjacent structures tend to be superimposed over the tooth. Also the canine may lie deep in the bone of the maxilla.

An intra-oral film for definition and a vertex occlusal X-ray with the tube parallel to the longitudinal axis of the upper central incisor are the views which are routinely taken (*Fig*. 3). The advantage of the vertex occlusal X-ray is that the frontal bone shadow is not superimposed on the canine. If there is difficulty in the location of the canine a lateral film can be taken (*Fig*. 4). Using these standard X-ray views the position of the maxillary canine can be located accurately. Ballard (1955) and Wraith (1969) have suggested that two films, lateral skull and postero-anterior views, should be taken to locate the canine. These lack the definition of an intra-oral film, and in the postero-anterior view considerable superimposition may still be present. Another disadvantage is that these films cannot be taken by most practitioners.

The Position of the Canine

An accurate assessment of the position of the canine is essential before treatment can be

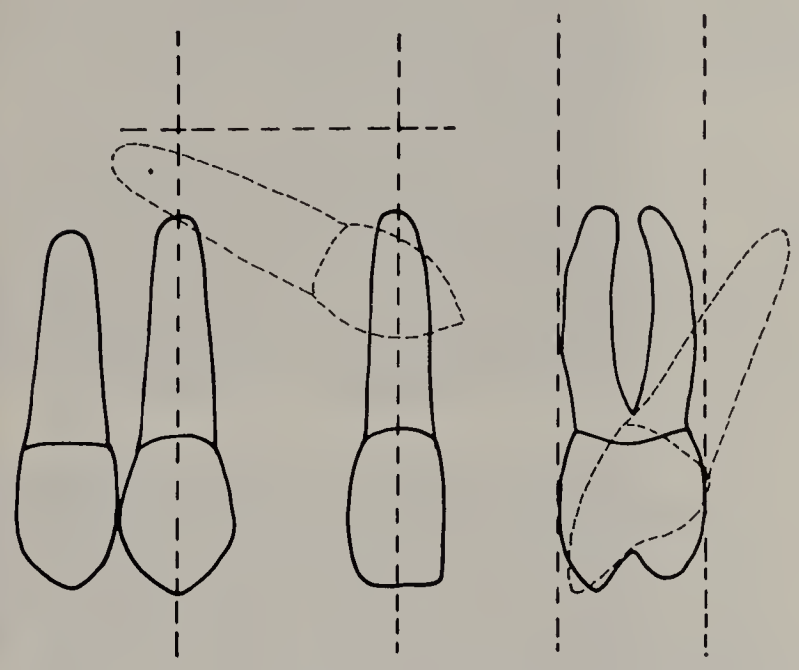


Fig. 5.—The guide lines used in assessing the position of the unerupted canine.

contemplated. Three things should be considered (*Fig*. 5):—

1. *The Position of the Apex*

The apex of the canine should lie mesial to the apex of the first premolar and distal to the apex of the lateral incisor. The apex should also lie within the alveolus, or would do so when the canine had erupted. It should also not be too high as in the older patient the final occlusal position is often not attained owing to failure of complete eruption of the canine.

2. *The Position of the Crown*

The position of the crown relative to the adjacent teeth should be carefully located and its influence on the neighbouring teeth assessed. The angulation of the lateral incisor can give some indication of the position of the crown, and this has already been discussed. If the tooth is firmly impacted against the adjacent tooth the prognosis of the canine is poor. The adjacent teeth should be carefully examined for signs of resorption of their roots.

3. *Direction of the Longitudinal Axis*

The direction of the longitudinal axis of the tooth must also be assessed. Will the tooth erupt or is it impacted against the adjacent teeth? When the tooth has erupted will the apex be in the correct position for the alinement of the canine? These are questions which must be considered when evaluating the position of the canine prior to the planning of treatment.

TREATMENT

Exposure of the Tooth

In order for exposure to be successful the following criteria must be present:—

1. There must be adequate space in the arch for the tooth.
2. The tooth must be able to erupt.
3. The exposure must be maintained during eruption of the tooth.
4. The buccal periosteum should not be removed during exposure of the canine. If it is removed the exposed teeth do not always erupt fully into a satisfactory position. It is interesting to note that as a general rule where a buccal flap has been raised the transplanted canines are not as successful as those where it has remained intact.

The older the patient at the time of exposure the less the chance of the tooth erupting fully into place, and often orthodontic treatment is required to aline the tooth after it has erupted.

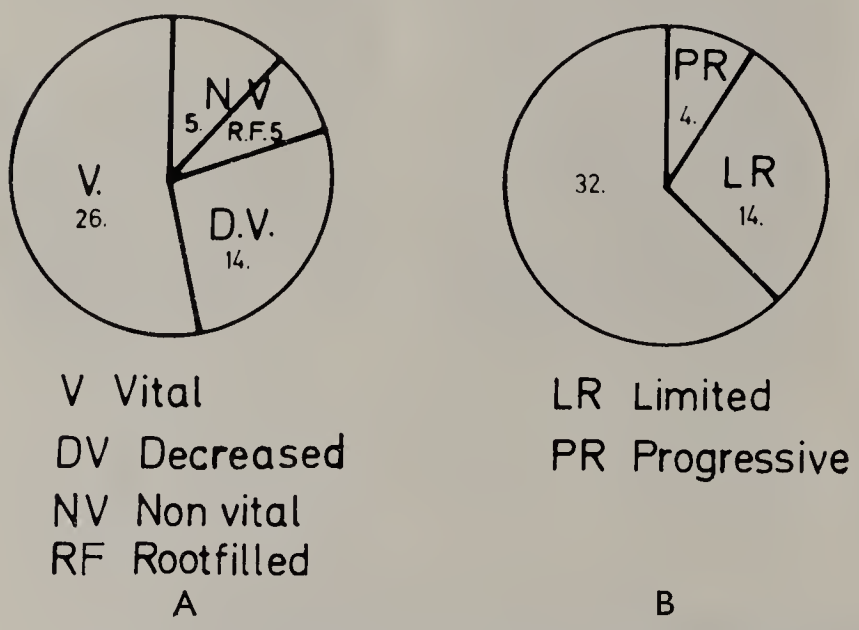


Fig. 6.—The results of 50 cases of canine transplantation considering (A) the vitality of the teeth and (B) the degree of resorption present.

Exposure and Adjuncts to Assist Eruption

Strock (1938) and Kettle (1951) advocated the exposure of a tooth and the fitting of a cap over the tooth in order to assist its eruption, but the criteria for exposure must be present. Pins into the cingulum of the tooth and lassooing the tooth with a soft stainless-steel wire have also been suggested to disimpact slightly impacted teeth. Pins tend to damage the erupting tooth and a filling is required when the pins are removed. Lassooing the tooth is a more satisfactory method although the time taken in alining the tooth may be considerable and may require fixed appliance therapy.

A soft stainless-steel ligature is placed around the neck of the tooth and the end projects into the mouth. An orthodontic appliance is used to apply traction to the end of the ligature wire, drawing the tooth down into position.

All these techniques are time consuming and often difficult, and a course of orthodontic treatment is necessary before the tooth is finally alined. This is a satisfactory method of treatment in the younger patient but in the older patient it is not the method of choice.

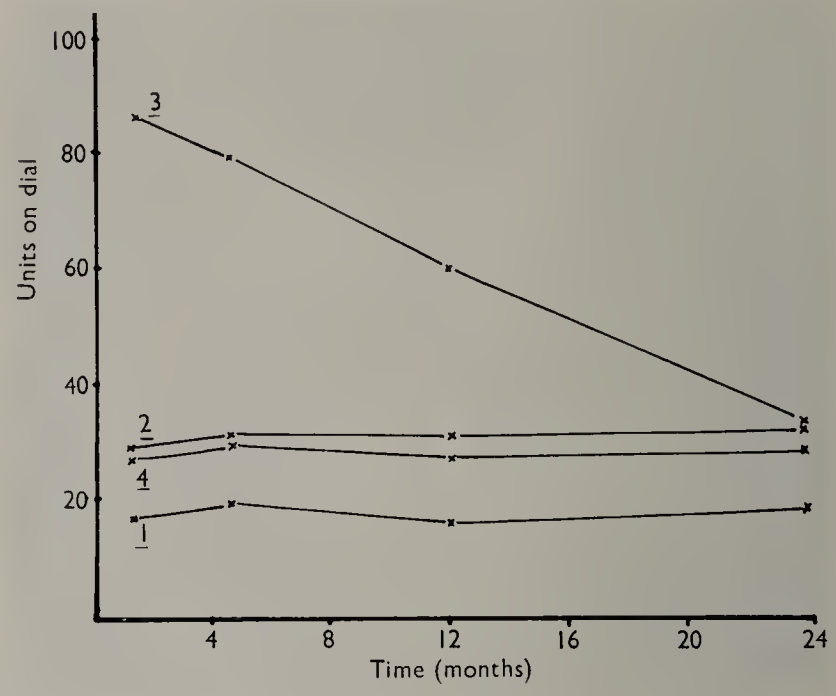


Fig. 7.—The vitality of an upper canine compared with the vitality of the adjacent teeth over a period of 2 years using an electrical pulp tester. The vitality of the canine improved over the period of time and after 2 years had a similar response to the neighbouring teeth.

Extraction

The extraction of the canine may be advocated if the canine is lying in an unfavourable position, there is insufficient space in the arch, and the morphology of the premolar is satisfactory and will make a good contact with the lateral incisor. If, however, the canine is lying high in the palate and is not likely to damage the adjacent teeth it may be left, as removal of the tooth results in the loss of bone around the remaining teeth.

Repositioning

In cases where there is adequate space in the arch and the canine apex is open and lies in the correct position mesiodistally and buccopalatally, surgical repositioning of the canine is possible. This must be undertaken at an early age and is not suitable for all cases (Holland, 1956; Cowan and Keith, 1961; McKay, 1961).

Transplantation

Often the older patient presents with a good arch and a retained deciduous canine which has become loose and aesthetically undesirable. In these patients the canine often lies in an unfavourable position with its apex closed, and the patient requests a minimum of treatment. In such cases

transplantation is indicated. Many people have described the transplantation of canines, root-filling the canine at the time of operation (Fordyce, 1965; Heslop, 1967; Hovinga, 1969). Widman (1916), the Swedish oral surgeon, transplanted canines and then root-filled them after they were firm. Fordyce (1965) estimated that root-filled transplanted canines would remain in the mouth for 5–10 years. Since this time Moss (1968) has described a method of transplanting canines without root-filling them, and Thonner (1970) has reported another method.

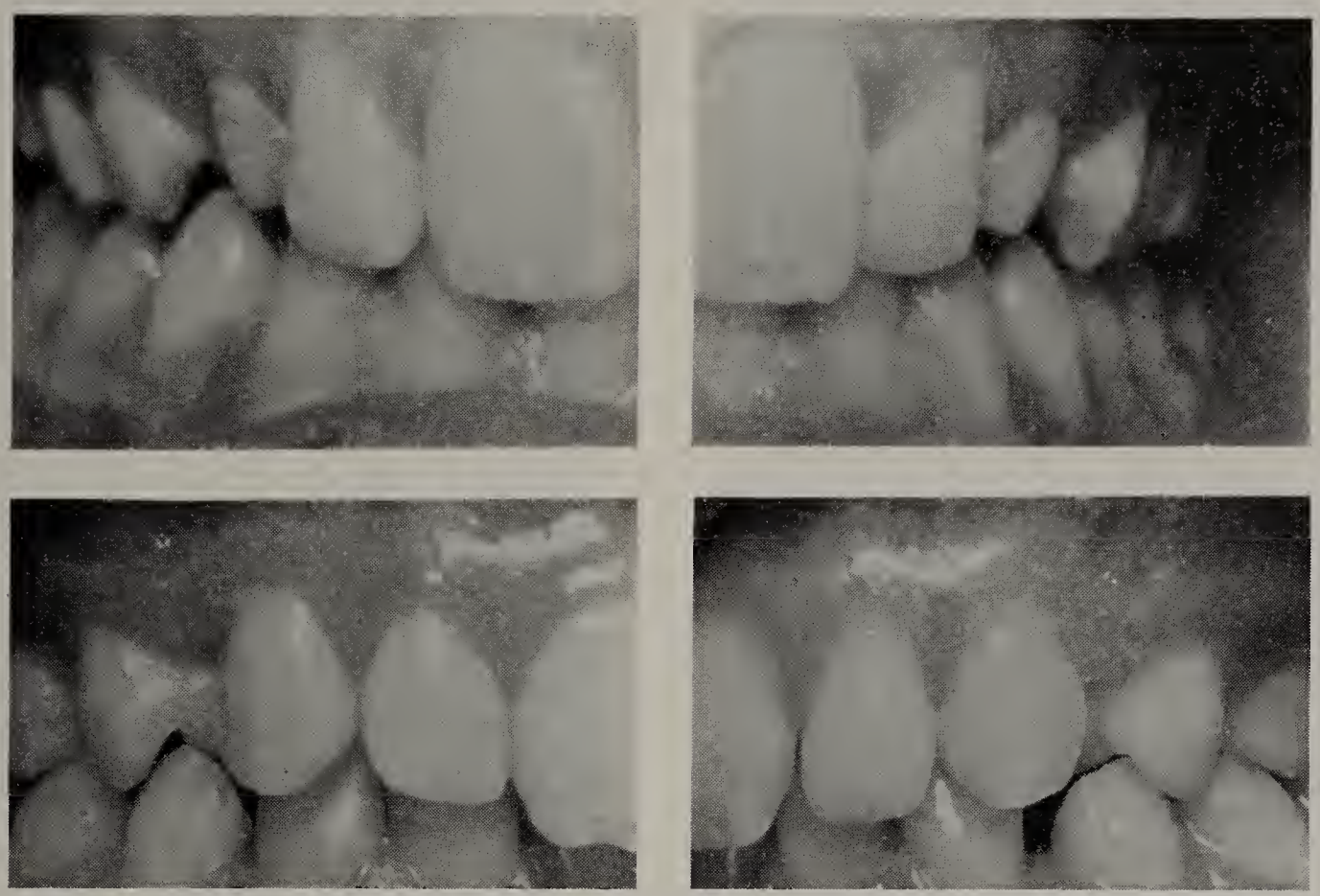


Fig. 8.—*Case* H.L. *Above*, Before the transplantation of $\underline{3|3}$. *Below*, $\underline{3|3}$ 3 years later.

METHOD OF TRANSPLANTATION

In patients where the canine tooth can be removed intact and there is adequate space in the arch the tooth is transplanted irrespective of its position and the state of its apex. If there is inadequate space present for the canine the space is reopened prior to transplantation.

A vacuum-formed acrylic splint is constructed over a replica of the canine to be transplanted which is positioned correctly on the alveolus. At least three teeth on either side of the tooth to be transplanted are covered by the splint and holes are cut with a small rosehead bur in the occlusal surface. This enables the operator to observe when the splint fits on the adjacent teeth and allows for the cement to escape, thus preventing it from being forced beneath the raised mucosal flap during the cementation of the splint. More teeth are covered with an acrylic splint because this is not as strong as a silver splint.

An incision is usually made palatally around the necks of the teeth from the first permanent molar to the canine on the opposite side of the jaw. The flap is raised and bone overlying the canine is carefully removed with a hammer and chisel. All bone is preserved in warm normal saline at body temperature. When sufficient bone has been removed to lift the tooth from its socket, bone is removed from the area where the tooth is to be placed, creating a new socket to receive the tooth. The canine is then placed in its correct position and the bone chips are placed around the root of the tooth. The palatal flap is sutured into position and the preformed splint is cemented with germicidal Kryptex cement. The patient is given prophylactic antibiotic cover for 5 days. The sutures are removed after 7 days and the splint is left for 4–6 weeks, after which time it is removed and the transplanted tooth is ground clear of the bite. This is important especially in the older patient where attrition of the deciduous canine has occurred and there is over-eruption of the lower canine.

RESULTS

Fifty cases which could be recalled 1–8 years out of retention have been included in the results (*Figs.* 6, 7).

The criteria used for assessing the results of these transplantations are the same as those used for the transplantation of third molars to first molar sockets by Fong (1953), Fong and Agnew (1958), Clark, Tam, and Mitchell (1954), and Nordenram (1963).

The gingival tissues were assessed for their colour and consistency, and the depth of the pockets was measured buccally, palatally, mesially,

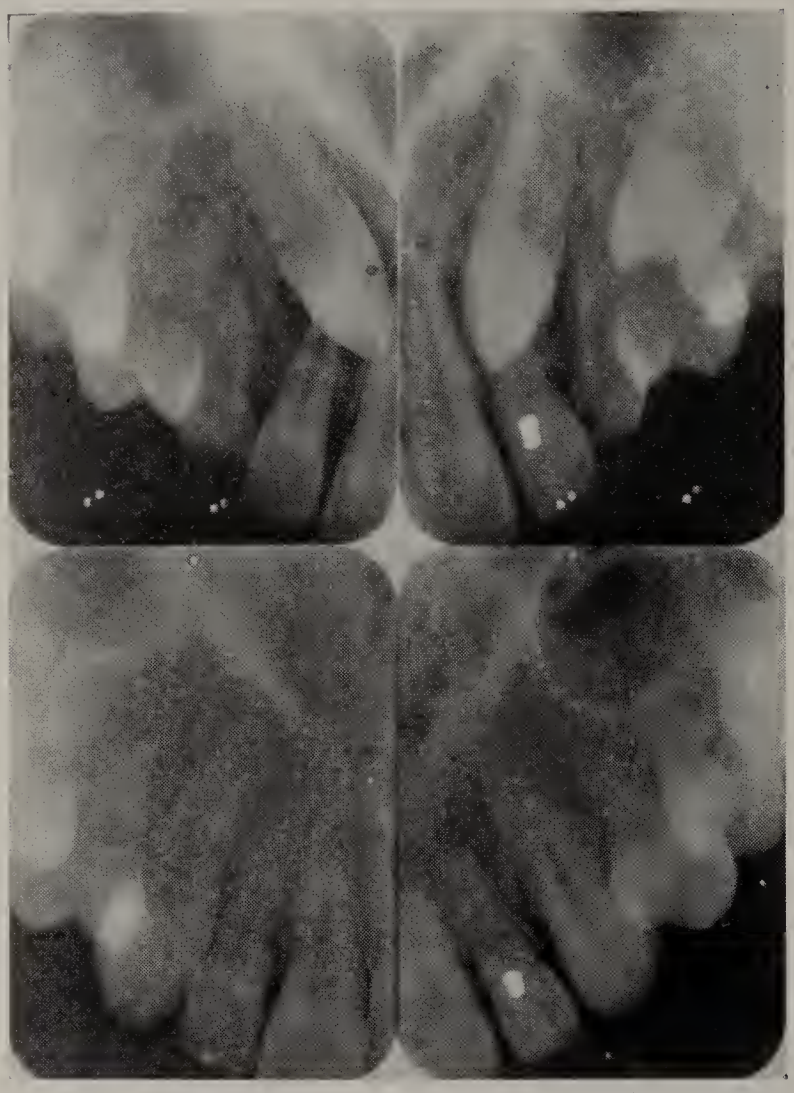


Fig. 9.—*Case* H.L. *Above*, The position of the canines before transplantation. *Below*, The position of the canines 3 years after transplantation. The $\underline{3|3}$ were both vital and responded at a similar level to the adjacent teeth on the electrical pulp tester.

and distally with a pocket measuring probe (*Fig*. 8).

The teeth were assessed as to their position, mobility, and whether there was contact between them and the adjacent teeth. The colour and vitality were also assessed by comparison with the opposite side and by using thermal and electrical stimuli.

Radiographic examination revealed the state of the alveolar bone, the lamina dura, the periodontal membrane, the presence of resorption, and the distance that the apex had moved (*Fig*. 9).

Gingival Tissues

Two of the 50 teeth which have been transplanted over the past 8 years have been lost. One was lost 18 months after operation and the other 3 years after operation. Both had been root-filled and both had infection of the area following transplantation. The gingival tissues were normal in 43 cases and poor in 5 owing to poor oral hygiene. The depth of the gingival pockets was 3–4 mm. in 15 patients and was less in all the other patients.

Mobility and Contacts

Twenty-eight teeth had good contacts on both sides, 11 had contacts on one side only, and 9

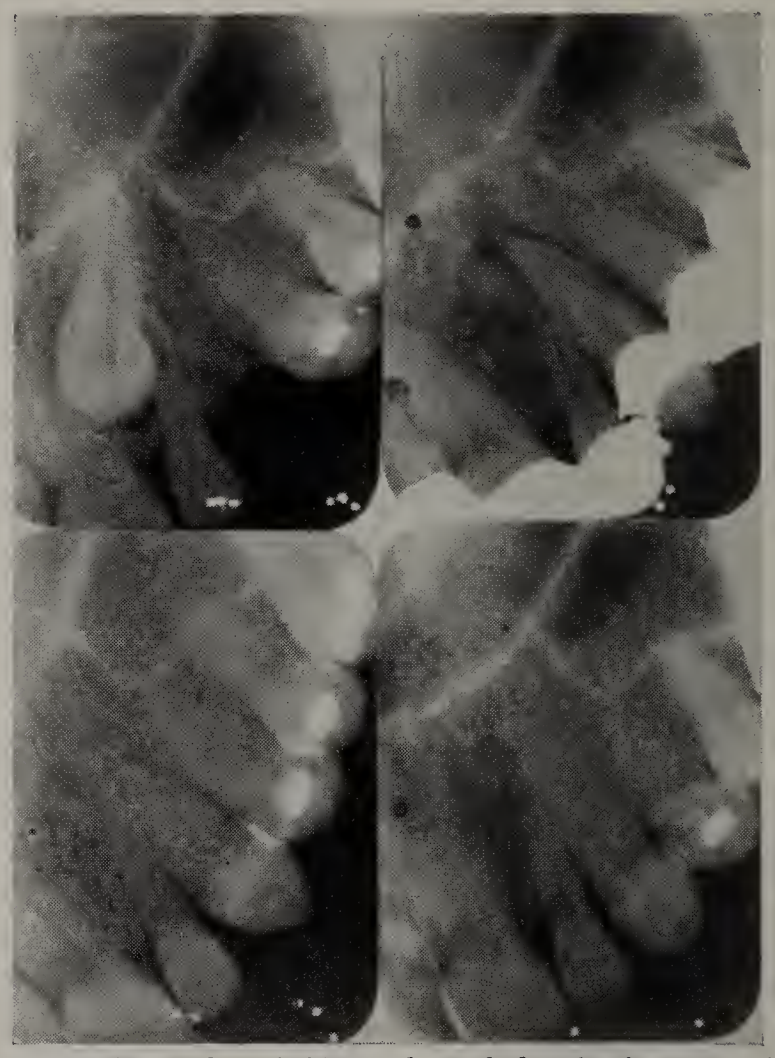


Fig. 10.—*Case* M.P. *Above left*, The intra-oral radiograph before transplantation of the $\underline{3|}$. *Above right*, The tooth 6 weeks after transplantation. *Below left*, Six months after transplantation there is evidence of resorption on the distal aspect of the root. *Below right*, Six years after transplantation.

had no contact. One tooth showed abnormal mobility and 2 had been extracted because of abnormal mobility.

Colour and Vitality

The colour was normal in 32 cases, slightly darker in 14, and dark in 2.

The vitality of the transplants was assessed with electrical and thermal stimuli. The vitality of some cases was followed over a period of time and some showed an increasing vitality over a period of 2 years (*Fig*. 7).

In the whole group 26 transplants had a normal vitality response compared with the other teeth in the mouth, 14 had a decreased vitality response, and 10 were non-vital. Of the 10 non-vital teeth, 5 had been root-filled because of periapical rarefaction and 2 have been extracted.

Resorption

Seventeen of the cases showed some resorption following the operation. This appeared to be of two types: a limited resorption immediately following the operation, most frequently on the

distal aspect of the tooth, which was usually repaired (*Fig.* 10); and progressive resorption which seemed to affect all aspects of the root surface. All except 1 of the root-filled teeth were being progressively resorbed.

Periodontal Membrane, Lamina Dura, and Alveolar Bone

In 39 cases the periodontal membrane, the lamina dura, and the alveolar bone were normal within 12 months of the operation. The bone of the mesial alveolar crest took longer to become apparent in 7 cases, and in 1 case was not present at the time of review.

Pulp Chamber

There was a decrease in the size of the pulp chamber in 21 of the cases, which indicated secondary dentine formation or calcification of the pulp (*Fig.* 11). Assessment of the canine by X-rays showed that in most cases the apex had been moved over a centimetre through the bone.

DISCUSSION

If the criteria for success with the transplantation of teeth is defined as a firm tooth which has a normal vitality and periodontal membrane surrounded by normal alveolar bone, 26 of the cases in the present series could be considered successful. This agrees with previous findings of Nordenram (1963) and Moss (1968, 1970).

The progressive improvement in the response of the tooth to thermal and electrical stimuli probably indicates a progressive re-innervation of the teeth. Nordenram (1963) examined the histology of transplanted teeth in monkeys and he noted that degeneration of the nerves occurred within 2 days of transplantation, but after 30 days new nerves were seen in the apical region and some entered the pulp chamber.

The cause of the resorption was probably due to the trauma during the removal of the tooth. The limited resorption on the distal aspect of the root of the canine seemed to correspond to the area of cementum that would have been damaged during the removal of the tooth. In some cases this was repaired. The progressive resorption was most frequently associated with teeth that were difficult to remove.

The decrease in the size of the pulp chamber was most frequently seen in the younger patients, indicating that in a younger person the pulp was more active and could respond by laying down calcific material. A similar phenomenon has been reported in transplanted teeth in animals (Fong and Agnew, 1958; Nordenram, 1963).

It appears from these results that the transplantation of canines can be attempted at any age, provided that there is adequate room for the tooth in the arch and that the tooth can be removed whole. The ultimate fate of the transplanted teeth will not be finally known for some years, but in the meantime they are giving good service and are aesthetically more pleasing than a bridge or partial denture.

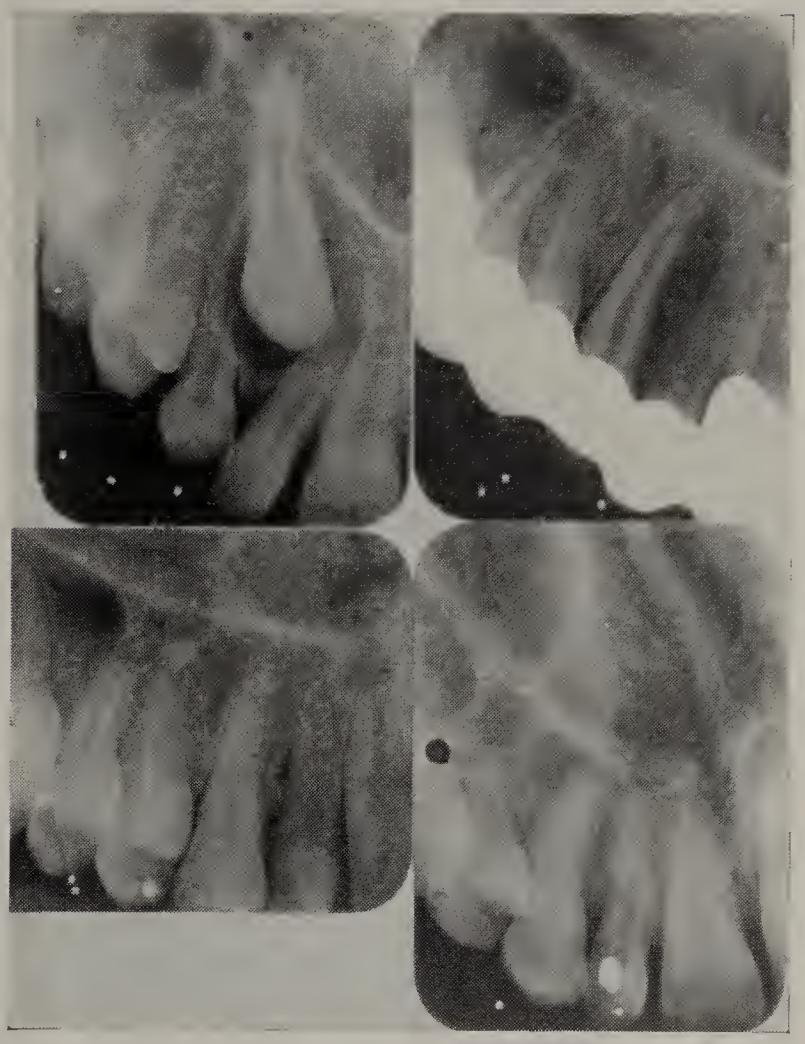


Fig. 11.—*Case* M.G. *Above left*, $\underline{3}|$ before transplantation. *Above right*, $\underline{3}|$ 6 weeks after transplantation. *Below left*, Nine months after transplantation the pulp chamber is decreasing in size. *Below right*, Three years after transplantation the pulp chamber is almost completely obliterated.

SUMMARY

The development and eruption of the normal canine have been reviewed and the criteria for assessing canines discussed. Various methods of treatment have been suggested and the results of transplantation of canines reported.

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TREATMENT OF A LARGE MAXILLARY MEDIAN DIASTEMA ASSOCIATED WITH FOUR SUPERNUMERARY TEETH

S. HAYNES, M.Ch.D., D.Orth., F.D.S. R.C.S. (Eng.), F.D.S. R.C.S. (Edin.)

Regional Orthodontic Service, Royal Infirmary of Edinburgh

DIASTEMATA, or excessive spacing of two consecutive teeth of the same series, rarely disturb occlusal function, but treatment may be requested for psychological and social reasons when the anomaly occurs between the central incisors. Moreover, the condition may be an additional feature in both Class II and Class III malocclusions, or, in contrast, it may be associated with an otherwise perfect dentition.

Gardiner (1956) found that the prevalence of median maxillary diastemata exceeding 2 mm. declined from 11·9 per cent at the age of 6–7 years to 0·5 per cent at 11–12 years. A similar low prevalence was also observed in 11–12-year-old children in a more recent investigation (Haynes, 1970).

Persistent median diastema differs from most other types of malocclusion in being almost invariably an expression of a low tooth: tissue ratio, i.e., an excess of bone tissue relative to tooth substance. Other associated congenital factors may also occur in the maxillary arch, such as diminished crown morphology, or absence of one or both maxillary lateral incisors, supernumerary teeth in the midline (mesiodens), and interdental extension of the labial fraenum. Paradoxically, the condition may also occur in the presence of maxillary crowding, if both lateral incisors are lingually positioned. More rarely, a median diastema may be acquired by digit-sucking habits, especially if the direction of the pressure applied causes both proclination and divergence of the maxillary central incisors.

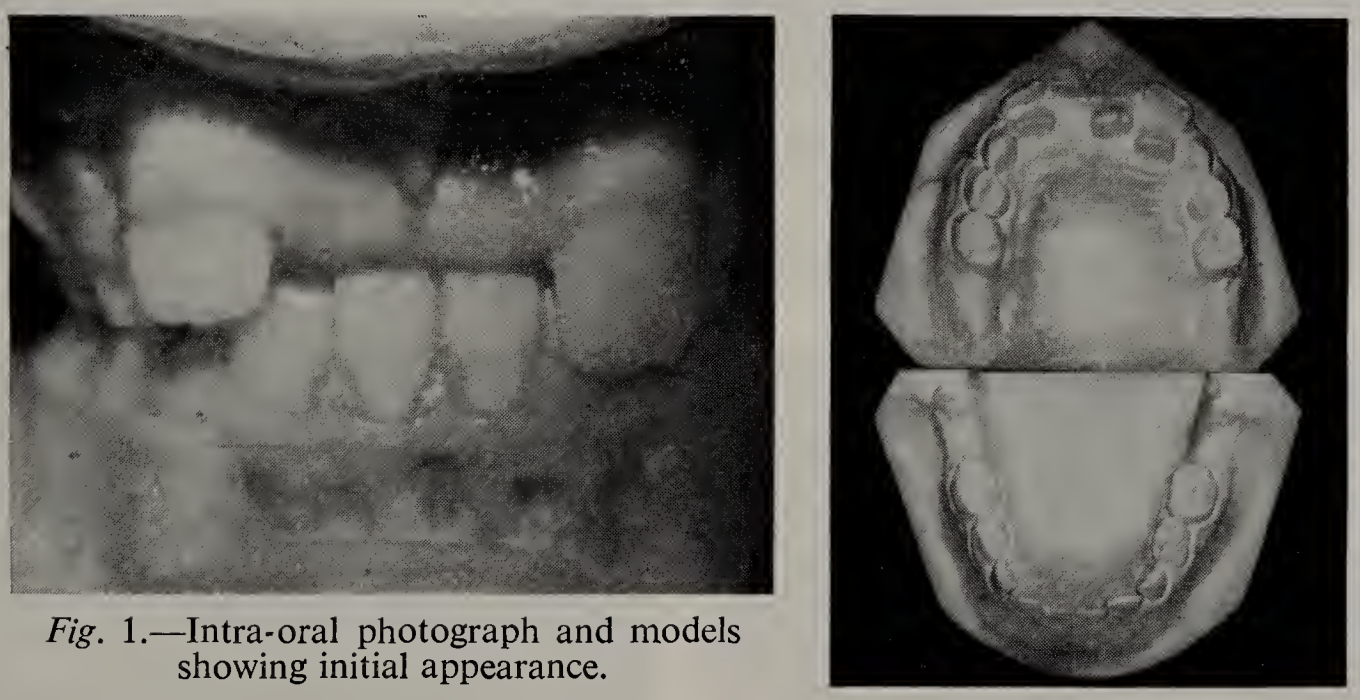


Fig. 1.—Intra-oral photograph and models showing initial appearance.

Because of the basic aetiological factor, a congenital median diastema is not amenable to correction by simple measures, particularly if the overjet is normal and there is involvement of the lateral incisors and insufficient space for a partial denture-retainer. Prognosis for closure of a diastema is often more favourable if a mesiodens is present, but the tooth: tissue ratio is again of fundamental importance and a careful analysis of each factor is necessary.

The case reported here is of clinical interest in view of the extreme displacement of all the maxillary incisors and the relatively small degree of relapse which followed tooth movements over a considerable distance.

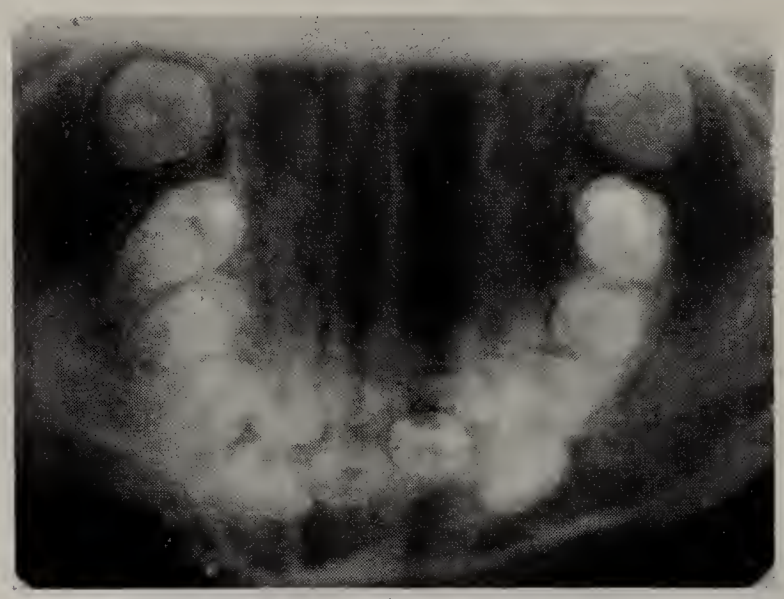
Presented at the Country Meeting held on 22 April, 1971.

CASE REPORT

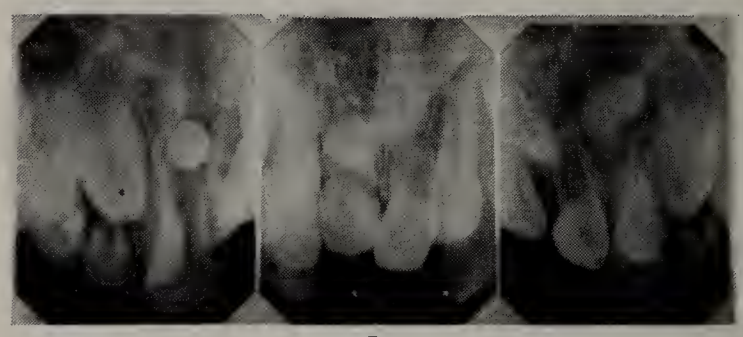
Nature of the Malocclusion

The patient, a boy aged 7 years, 3 months, was first examined in February, 1964, at the request of his dental practitioner. He had previously attended the Edinburgh Dental Hospital for conservation of the deciduous molars.

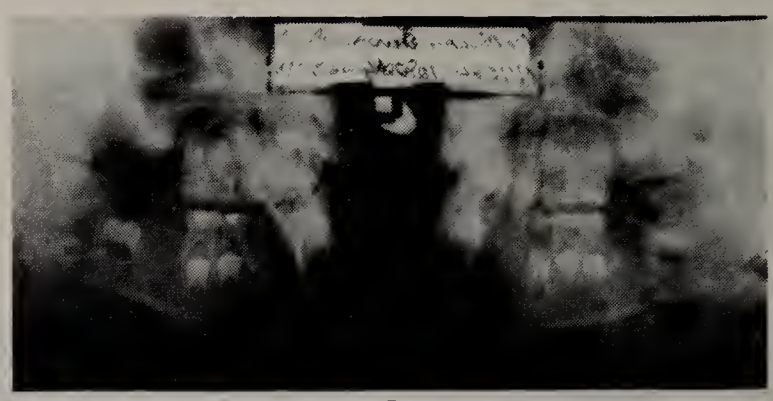
Visual inspection showed that the permanent central and lateral incisors and the deciduous canines and molars were present in each quadrant. The maxillary central incisors were 17 mm. apart at their mesial–incisal angles, and an erupted supernumerary tooth was present in the left maxillary central incisor region. The maxillary lateral incisors were in lingual occlusion and were palatally related to the central incisors (*Fig.* 1). The occlusion of the buccal segments was normal.



A

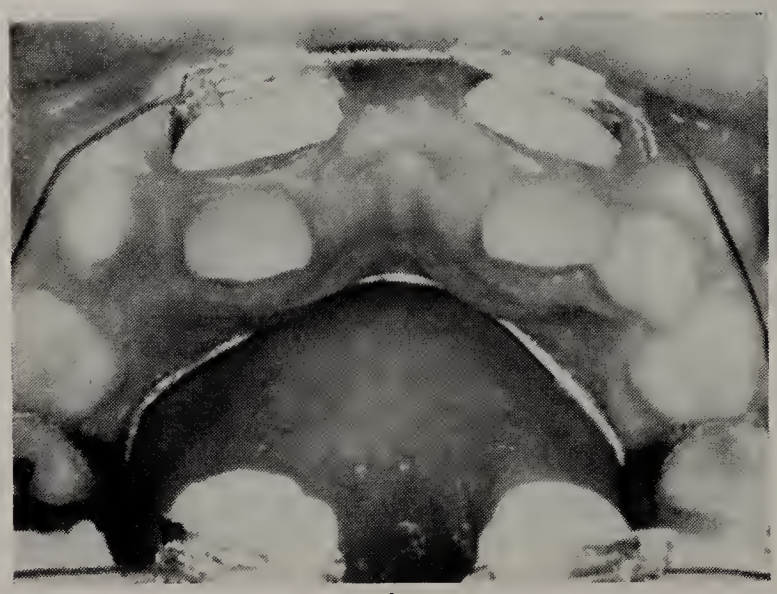


B

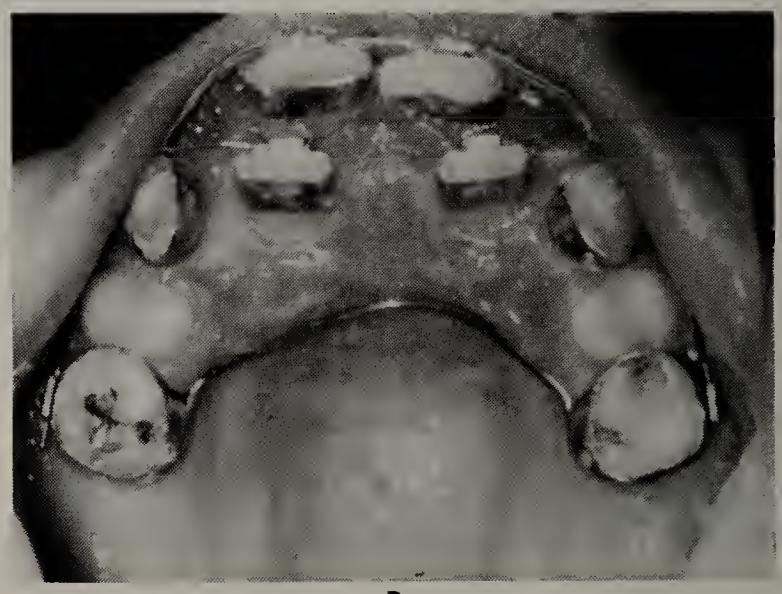


C

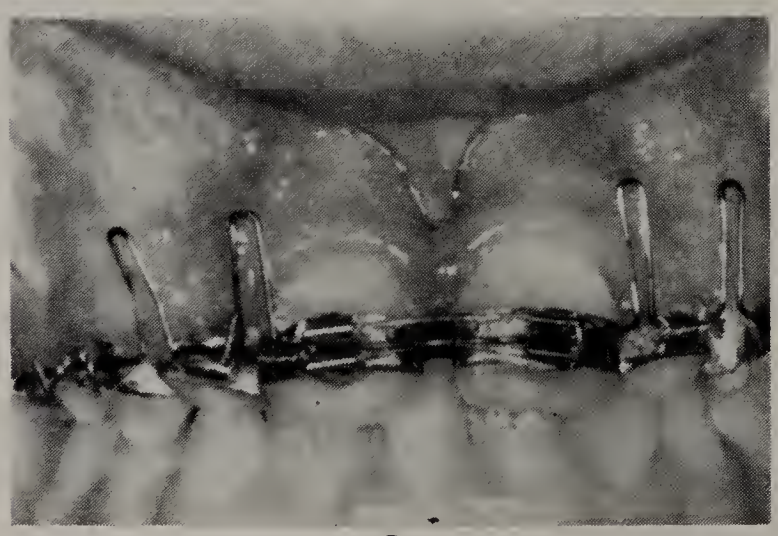
Fig. 2.—Radiographic appearance on examination: (A) occlusal, (B) anterior, and (C) lateral views. The anterior views show the presence of four supernumerary teeth in the midline, i.e., two supplemental incisors between $\underline{1|1}$ and two ' canineiform ' teeth between $\underline{2|2}$—the one on the left side is inverted. Absence of all first permanent molars is evident from the lateral jaw films.



A



B



C

Fig. 3.—A, Extended coil spring to approximate $\underline{1|1}$. B, Twin-wire arch with compression springs to complete closure of the diastema and to tilt $\underline{2|2}$ labially. C, 0·016-in. looped archwire to rotate and aline $\underline{2|2}$.

Radiographic examination revealed three other unerupted supernumerary teeth in the maxillary incisor region, and also confirmed the presence of the unerupted permanent canines, premolars, and second permanent molars (*Fig.* 2). The referring practitioner subsequently confirmed that the first permanent molars had been removed when the patient was aged $6\frac{1}{2}$ years.

Treatment

Treatment objectives were limited to the maxillary arch, i.e., alinement of the incisors following surgical removal of the supernumerary teeth. Permanent retention was also advised because of the probability of relapse subsequent to tooth movements over the large distances involved. The oral surgery was performed in May, 1964. The supernumerary canine in the left maxillary lateral incisor region was retained at operation on account of its deep position and the improbability that it would adversely affect the orthodontic treatment.

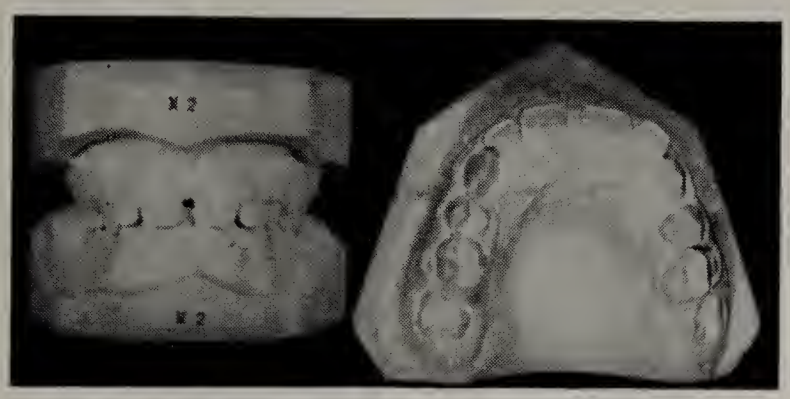


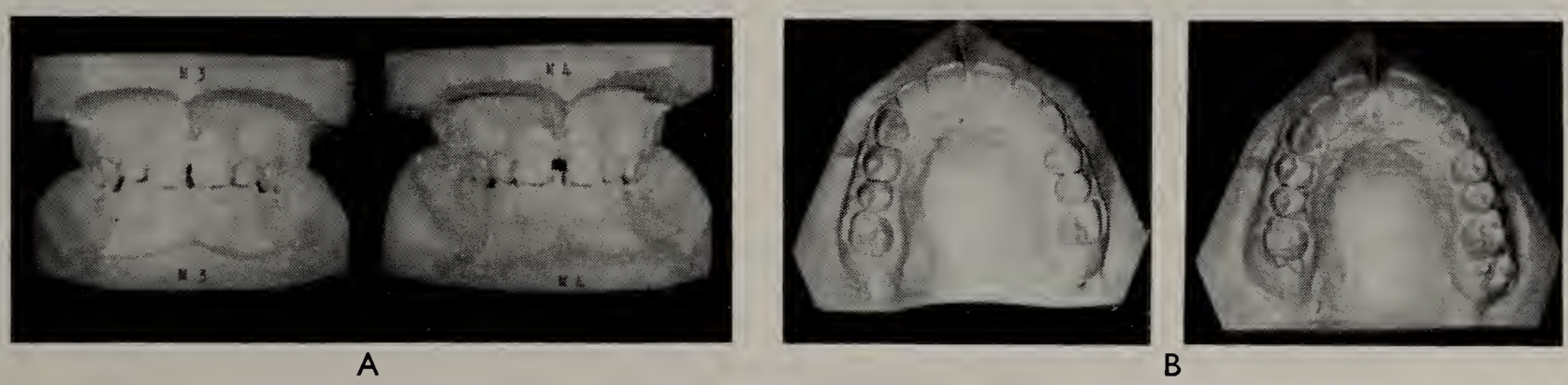
Fig. 4.—Models showing progress prior to exfoliation of E|E.

One month later an orthodontic appliance was cemented to E1|1E. The appliance consisted of a labial archwire and a median coil spring which was extended by steel ligatures into twin-wire arch brackets attached to the central incisor bands (*Fig.* 3A). The diastema decreased to 3·5 mm. within 8 months, and further space closure was achieved by means of a twin-wire arch having compression springs distal to the central incisors. Correction of the lateral incisors was also commenced at this stage (*Fig.* 3B), and their alinement was further improved by means of a 0·016-in. (0·4 mm.) looped archwire (*Fig.* 3C). Appliance therapy was then discontinued for 20 months, as exfoliation of the second deciduous molars occurred rapidly (*Fig.* 4) and the rate of eruption of the second permanent molars was extremely slow. Five months following removal of the appliance, the diastema had relapsed to a maximum amount of 5 mm.

The second period of treatment commenced in May, 1968, and normal axial incisor inclinations were restored by utilizing Begg brackets and root springs. The appliance was also used as a retainer for 6 months before its removal in July, 1969 (*Fig.* 5). A removable retainer was fitted within 24 hours, but as this was not worn, permanent retention of the case as envisaged was not feasible.

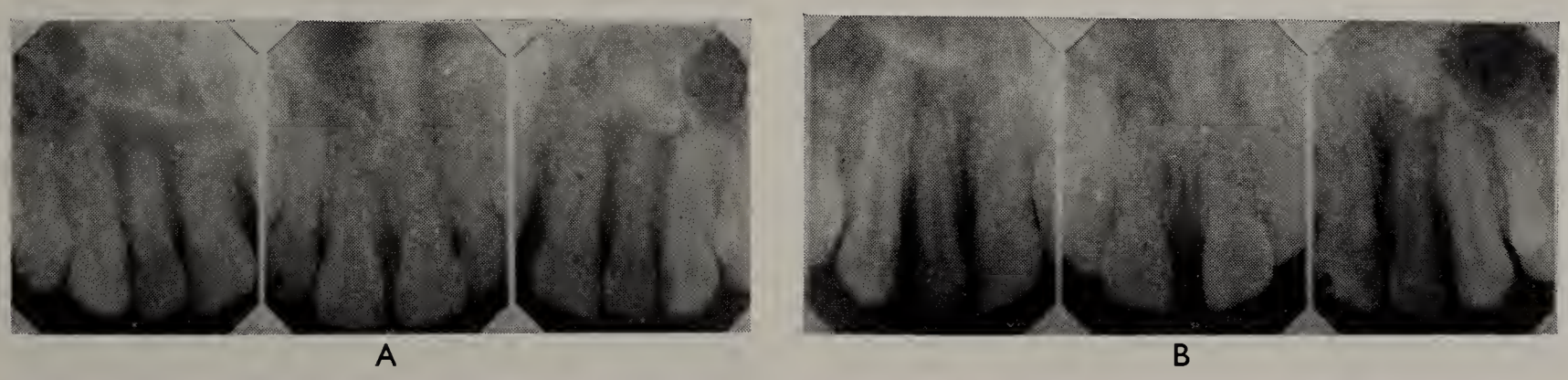
Post-treatment Changes

The patient attended for further examination in November, 1970, i.e., 16 months after appliance removal. Records obtained on this occasion show some reappearance of the diastema together with an increase in incisor overbite, proclination, and slight rotation of the maxillary central incisors (*Fig.* 5).



A B

Fig. 5.—Frontal (A) and occlusal (B) views of models showing post-treatment changes. The models on the right side of each figure show the appearance 16 months after appliance removal.



A B

Fig. 6.—Radiographic appearance of maxillary incisor region. A, On completion of active treatment (July, 1969). B, Sixteen months after treatment (November, 1970).

The post-treatment radiographic changes in the maxillary incisor region and the radiographic appearance on completion of treatment are shown in *Fig.* 6.

Superimposition of the radiographs of February, 1964 (pre-treatment), July, 1969 (final band removal), and November, 1970 (16 months out of retention), is of interest. The changes in the positions of the maxillary central incisors are shown diagrammatically in *Fig.* 7, and the relatively slight change occurring in the post-treatment period may be observed.

In *Table I* the distances between the maxillary incisors, before, during, and after treatment, are compared and it can be seen that the diastema was reduced from 17 to 2 mm. and that it finally relapsed to 3·5 mm. *Table I* also shows that comparable dimensional changes occurred between the distal

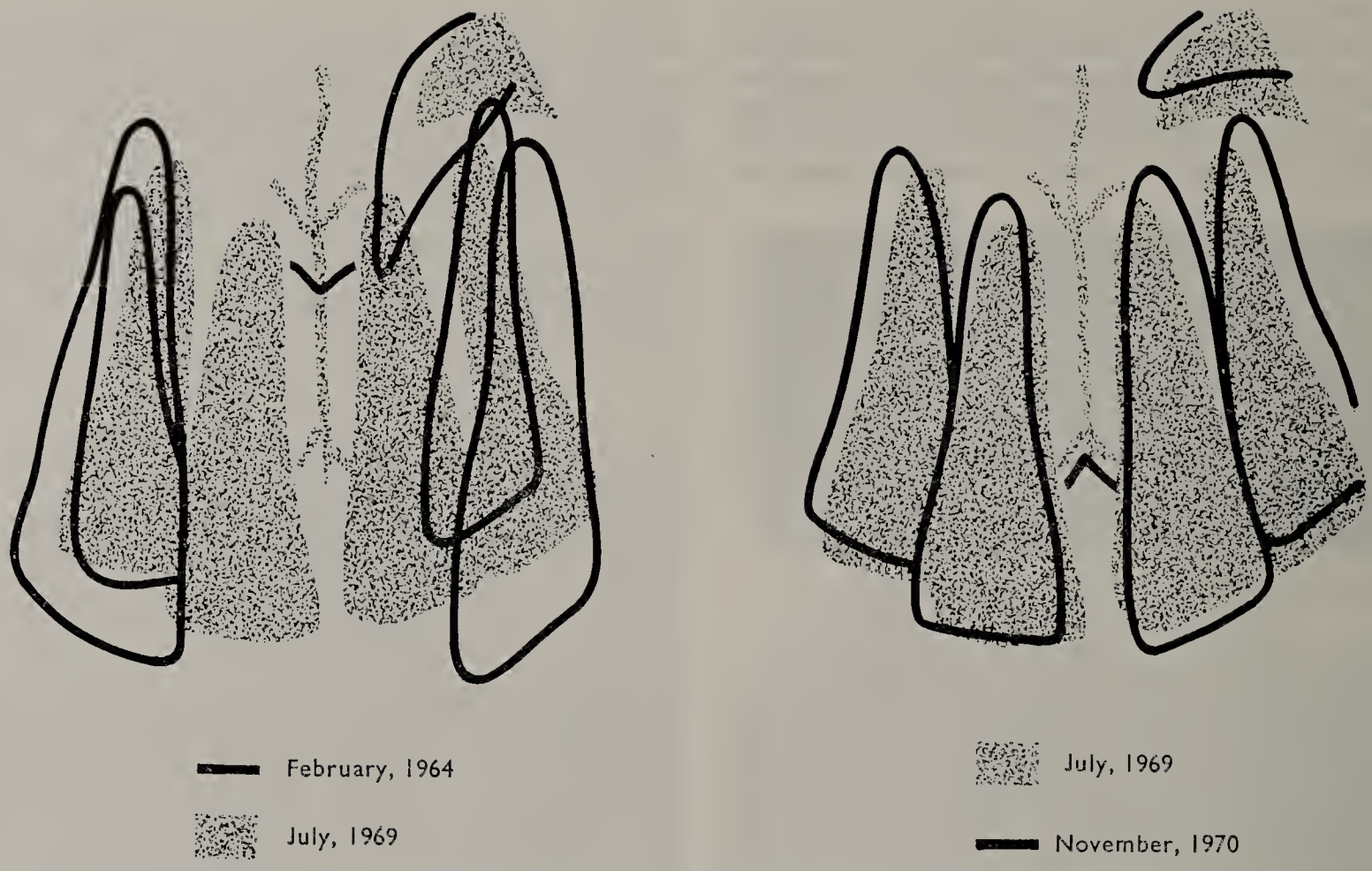


Fig. 7.—Composite diagrams of superimposed intra-oral radiographs.

Table I.—Changes in Incisor Positions during Treatment

Date	Width of Diastema at Incisal Edge (mm.)	Distance between Distal Surfaces $\underline{1}\vert\underline{1}$ (mm.)	Distance between Distal Surfaces $\underline{2}\vert\underline{2}$ (mm.)
February, 1964	17·0	32	27
August, 1966	2·0	19	33
July, 1969	2·0	19	32
November, 1970	3·5	21	32

surfaces of the maxillary central incisors. There was no corresponding change, however, between the distal surfaces of the maxillary lateral incisors in the post-treatment period.

SUMMARY

Treatment of a large median maxillary diastema associated with four supernumerary teeth is described. Continuity of treatment was seriously impaired by early extraction of the first permanent molars, and there was a delay of 20 months between the first and second phases of active treatment.

Fixed retention was maintained for 6 months after complete closure of the diastema, and a 20 per cent relapse was observed 16 months later.

Acknowledgements

The co-operation of Mr. A. E. Duvall, Consultant Dental Surgeon, and of Dr. G. B. Hopkin and staff of the Orthodontic Department, Edinburgh Dental Hospital, is much appreciated.

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THE DISPLACED MAXILLARY CANINE: POSITIONAL VARIATIONS ASSOCIATED WITH INCISOR RESORPTION

R. D. HOWARD, B.D.S., F.D.S., D.Orth.

King's College Hospital Dental School, London

SECOND only to the mandibular third molar in frequency of impaction, the displaced maxillary canine tooth is a clinical entity having an incidence variously estimated at between 0·92 per cent (Dachi and Howell, 1961) and 1·6 per cent (Thilander and Jakobsson, 1968). The occasional and therefore unusual case that produces the complication of incisor resorption, has been less well studied, probably because of its infrequency. It was in an attempt to understand the reason for the aberrant behaviour of some displaced canines that the present investigation was undertaken, and it was hoped that it might prove possible if such understanding were achieved to predict which cases would be likely to suffer this unfortunate complication.

MATERIALS AND METHODS

Since it was likely that an investigation of positional relationships would prove the most profitable avenue of exploration, this study was designed with this in mind.

In order to pinpoint the displaced maxillary canine tooth in three dimensions and to establish with some degree of accuracy its relationship to other teeth and anatomical structures a comprehensive and standardized radiographic coverage was required and consisted of the following films:—

1. Intra-oral film showing the canine tooth and the root of adjacent tooth.
2. Vertex occlusal film showing the bucco-lingual and the mesiodistal disposition of the canine tooth.
3. Cephalometric lateral skull film with increased penetration to show the position and relationship of the displaced canine.
4. Postero-anterior skull film taken at the same tube–film distance as the cephalometric lateral skull film but with the nasal floor orientated in a horizontal direction.

The films were carefully examined after exposure to ensure that they were of adequate readable quality before the case was included in this series.

The series consists of 52 patients having displaced maxillary canine teeth, 7 of whom have demonstrable incisor resorption and 45 cases acting as controls. The controls were consecutive unselected cases passing through the Orthodontic Department for treatment.

Resorption Group

The patients in this group were aged between 11 and 16 years and consisted of 2 boys and 5 girls. This, rather interestingly, was exactly the ratio that Röhrer (1929) showed to be the ratio of males to females for the incidence of displaced canines generally.

Before discussing the more detailed findings of the radiographic examination it should perhaps be made clear what criteria were required before a case was included in this group. Resorption was indicated when a case showed both of the following features:—

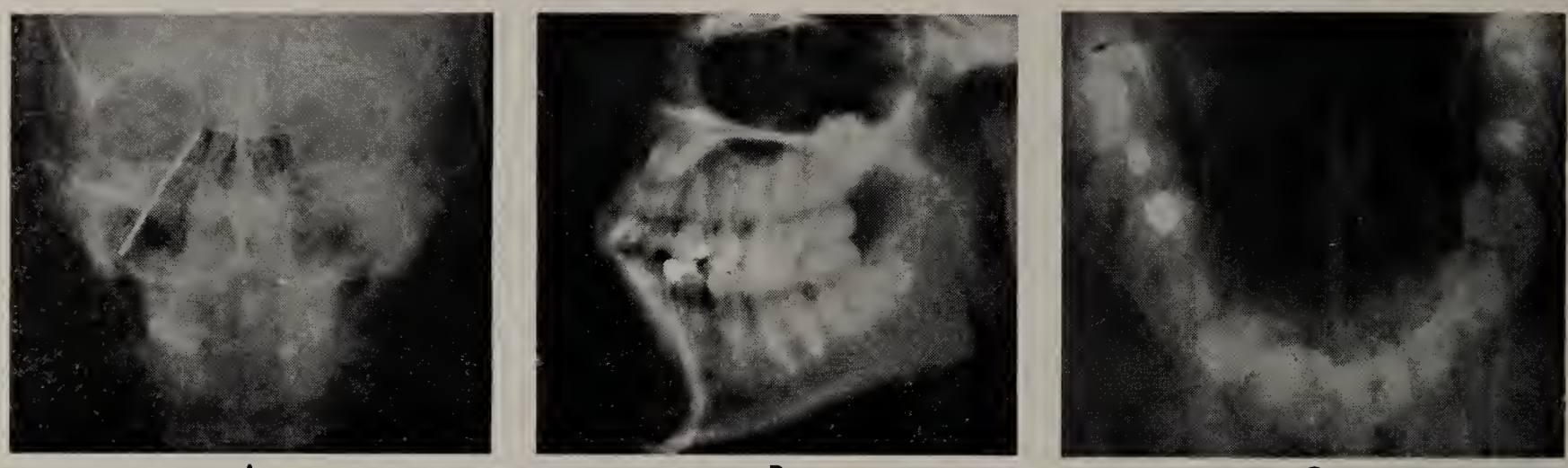
1. Loss of normal apical contour, i.e., the normal paraboloid shape was lost from the apical region and was replaced either by a flattened or a concave root profile.
2. Loss of root length.

Both of these changes are gross changes and are unlikely to be misinterpreted. They are also late changes. Small degrees of apical resorption particularly on the labial or palatal root surfaces of incisors which do not allow a projected profile X-ray view to be obtained may often go undetected until the more gross changes of root shortening make the resorptive process apparent. Since the rate at which the resorptive process proceeds is not known with any degree of accuracy it is possible that these early stages may be passed through rapidly and early detection may not be possible even with more sophisticated X-ray techniques.

Presented at the Country Meeting held on 23 April, 1971.

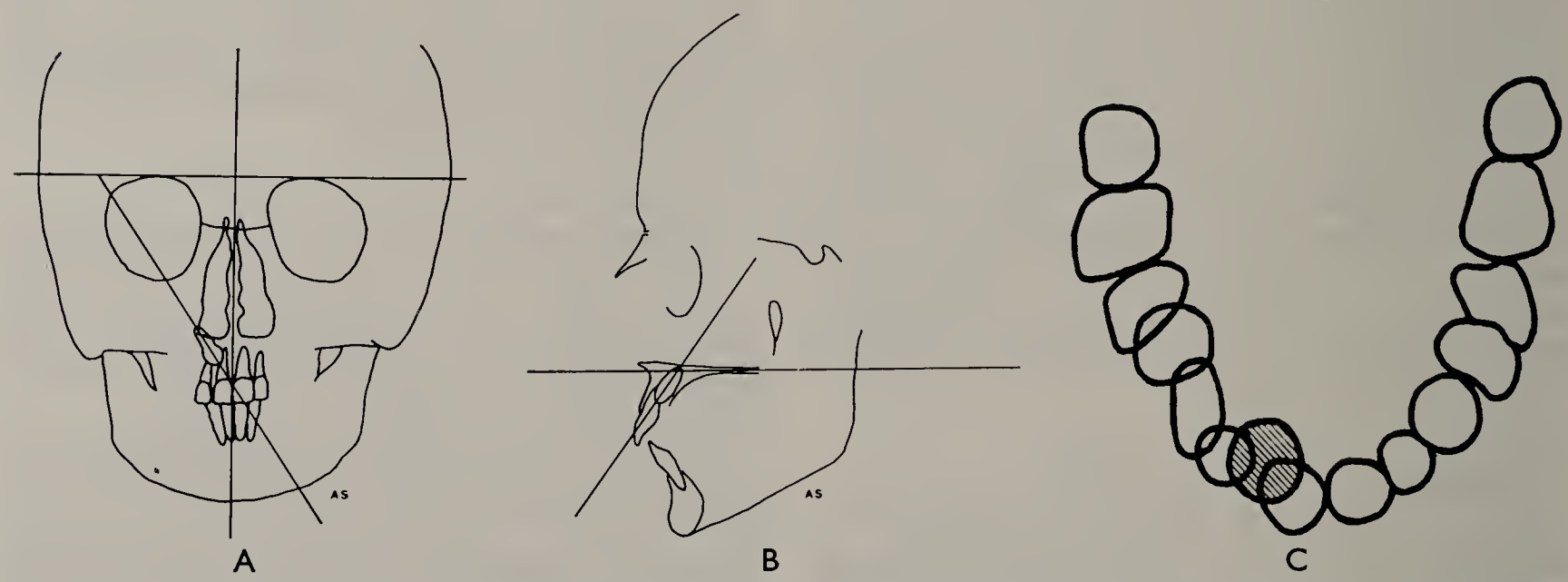
1. *Intra-oral Film*

This view showed a degree of resorption of between one-quarter and one-half incisor root length. The relationship between the crown of to the close relationship formed by the canine tooth to the incisor roots and in some cases the axial inclination of the canine tooth placed it above the level of the incisor apices and made it



A B C

Fig. 1.—A, Postero-anterior skull film showing $\underline{3}|$ rather vertically placed over the roots of $\underline{21}|$. B, Part of cephalometric lateral skull film showing the similarity of axial inclination of the canine and the incisors. C, Vertex occlusal film with the outline of $\underline{3}|$ between $\underline{2}|$ and $\underline{1}|$. Lack of root outline indicates vertical disposition.



A B C

Fig. 2.—A, Tracing of postero-anterior skull film showing steep axial inclination of the canine to the mid-sagittal plane. B, Tracing of lateral skull film showing the coincident axes of the canine and incisors. C, Tracing of vertex occlusal film emphasizing the lack of deviation from the vertical of the canine.

the displaced canine tooth and the root of the affected incisor seemed to be intimate and in all cases the canine crown appeared to be occupying the area that would have been occupied by the incisor apex had it not been resorbed. (This information was deduced from the use of the vertical occlusal film as well as from the intra-oral film.) In all cases it was the enamel surface of the canine crown that formed the nearest relationship to the resorbed incisor apex. Some degree of follicular enlargement was seen in 3 cases.

2. *Vertex Occlusal Film*

Although this view was useful in determining the buccolingual direction of the crown or root deviation, generally speaking the information that was gained from this view was less than was anticipated. The reason for this was largely due difficult to separate the superimposed images. Taken in conjunction with the next two views, corroborative evidence was obtained about the axial inclination of the teeth under consideration.

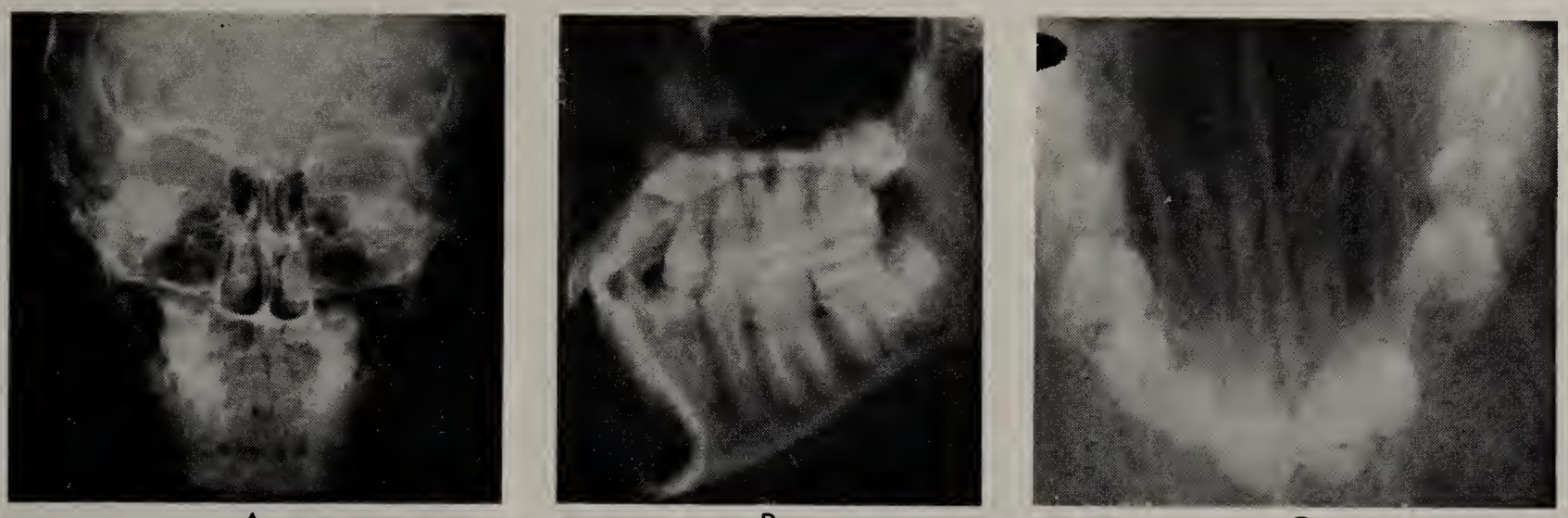
3, 4. *Cephalometric Lateral Skull and Postero-anterior Films*

It was felt from the beginning of this investigation that the proximity of the canine crown to the apices of the incisor teeth was the critical factor in the initiation of the resorptive process. The intra-oral and vertex occlusal views appeared to confirm this but it was only by a close scrutiny of the more standardized cephalometric lateral skull and postero-anterior views that the true vertical height and labiolingual inclination of both the canine and the incisors were determined. It was also by the use of these films that the

manner in which the close approximation achieved was determined. Since both films provide complementary information they will be considered together.

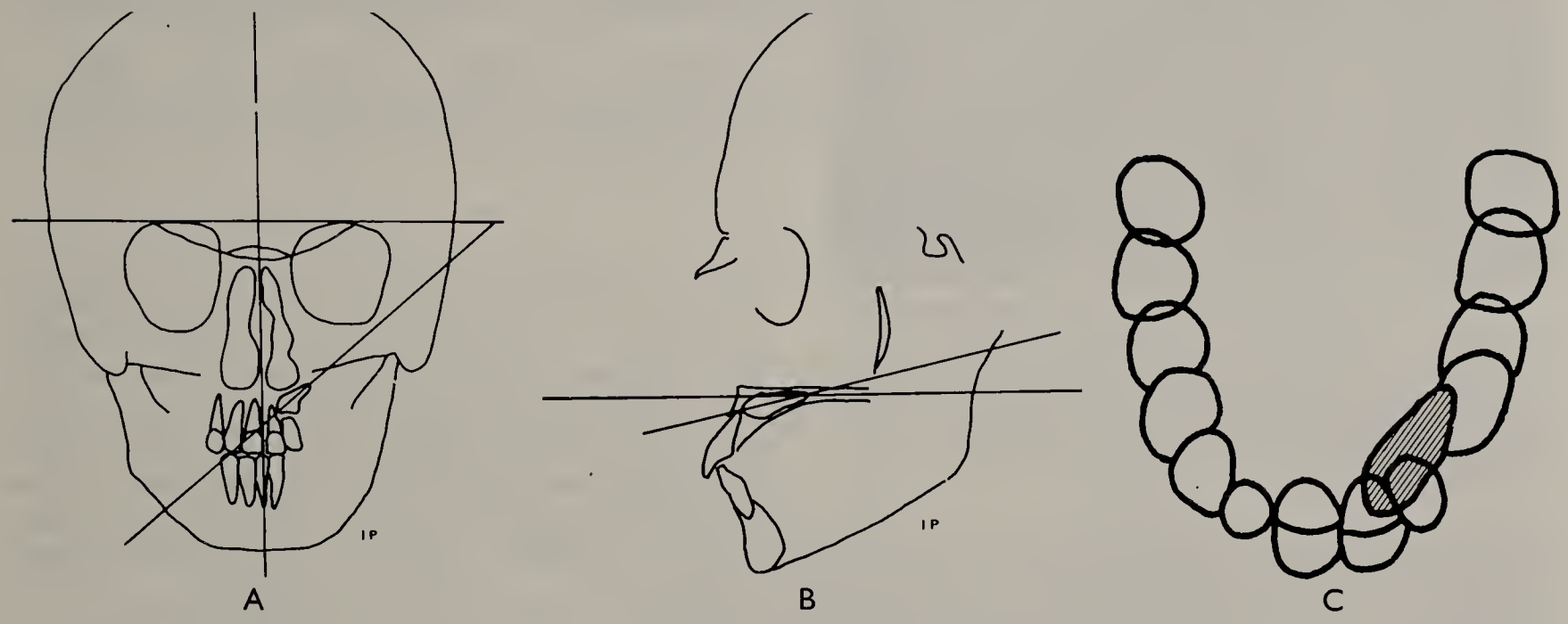
1. Vertical Group (*Table I*)

This group showed clear differences from the other groups and since it was characterized by a more vertical position of the canine tooth this



A B C

Fig. 3.—A, Postero-anterior skull film in which $\underline{|3}$ is presenting just below the nasal floor. B, Part of cephalometric film with a displaced canine tooth parallel to the nasal floor. C, Vertex occlusal film in which $\underline{|3}$ is only just visible passing distally to $\underline{|2}$.



A B C

Fig. 4.—A, Postero-anterior skull tracing showing the extreme oblique angle of the canine to the midsagittal plane in this group. B, Lateral skull tracing with the canine tooth nearly horizontal and on an intersecting course with the incisor roots. C, Vertex occlusal tracing showing the entire canine profile arising and in line with the buccal segment.

ANALYSIS

A considerable range of variation in canine position both in the lateral skull film and in the postero-anterior skull film was found but it was apparent that the variation did allow some groupings to be made. The lateral skull films and postero-anterior skull films were then traced and the groupings formed originally were confirmed.

The lateral skull film was traced to show the angle subtended by the unerupted displaced canine tooth to the maxillary plane, and the postero-anterior skull film was traced to show the angle subtended by the canine tooth to the midsagittal plane.

has given the name to the group. The postero-anterior skull film shows the lowest subtended angle of any of the groups and consequently the most vertical position for the canine in this plane (*Fig*. 1A). The lateral skull film shows the rather vertical position in this plane and confirms the intersecting course of the canine with the roots of the incisor teeth (*Fig*. 1B). The vertex occlusal film offers contributory evidence of the small amount of deviation from the vertical of the canine tooth (*Fig*. 1C).

In order to assist in visualizing the position of the canine, diagrams have been derived from tracings of the lateral skull, the postero-anterior skull, and the vertex occlusal films and these may

be seen in *Fig.* 2. The projected line from the canine tooth in the postero-anterior skull film may be seen to cut the supra-orbital plane within the compass of the cranium outlined. This will not be found to be true in the other groups.

2. Horizontal Group (*Table I*)

This group presented with almost exactly the opposite features of the previous group. The lateral skull film gives angular readings that show the canine to be approaching the horizontal (*Fig.* 3B), the long axis of the canine tooth appearing to form a relationship at right angles to the axis of the affected incisor tooth. The postero-anterior skull film shows the lack of deviation of the canine tooth from its essentially antero-posterior path (*Fig.* 3A). The vertex occlusal film shows the radicular part of the canine tooth more clearly than the coronal part since the latter is masked by the superimposition of the incisor root and crown (*Fig.* 3C).

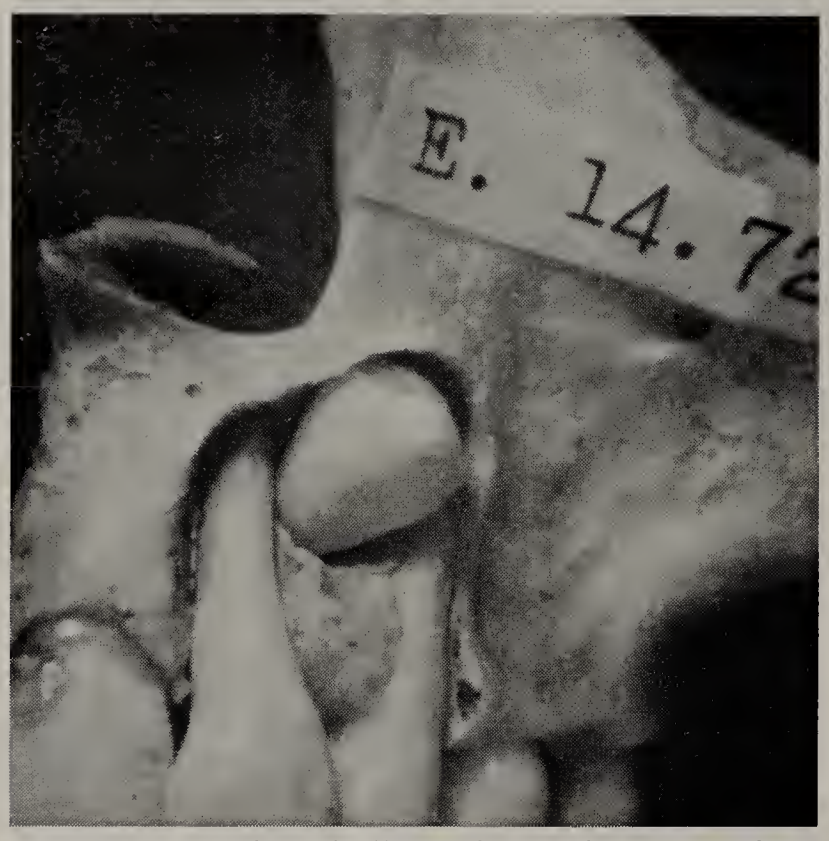


Fig. 5.—Dried skull specimen showing a displaced canine tooth perforating the buccal plate of bone immediately distal to the lateral incisor root. (*From the Odontological Museum of the Royal College of Surgeons of England by courtesy of the Curator*).

Further diagrams have been derived from lateral skull tracings to clarify the situation with regard to the horizontal group and these are shown in *Fig.* 4. The extension of the line passing through the canine tooth in the postero-anterior skull film will be seen to pass through the supra-orbital plane at a point well outside the outline of the calvarium.

It is possible that with teeth in this group the possibility of damage to incisor teeth may be avoided by small changes in angular inclination, particularly around the horizontal plane (*Fig.* 5). In this museum specimen the canine tooth has perforated the alveolar bone on the buccal side of the maxilla but has avoided causing damage to the root of the lateral incisor.

3. Lateral-horizontal Group (*Table I*)

In this group the features are less clear-cut than in the previous groups. The lateral skull film shows the canine tooth at approximately the same angle as in the vertical group but some degree of foreshortening of the tooth is apparent (*Fig.* 6B). The postero-anterior skull film shows the increased internal angulation of the vertical group and the canine tooth appears to be tending to pass palatally to the incisor teeth (*Fig.* 6A). The vertex occlusal film shows some part of the palatal outline of the canine tooth as it projects from the palatal outline of the incisor crowns (*Fig.* 6C).

Table I.—The Position of the Canine in the Four Groups

Group	Patient	Angle of Canine on Radiograph	
		Lateral Skull	Postero-anterior
Vertical	M.D. A.S.	103°/109° 124°	33°/33° 26°
Horizontal	L.B. I.P.	145° 163°	53° 51°
Lateral-horizontal	K.M. B.M.	109° 111°	69° 45°
Unallocated	S.D.	140°	42°

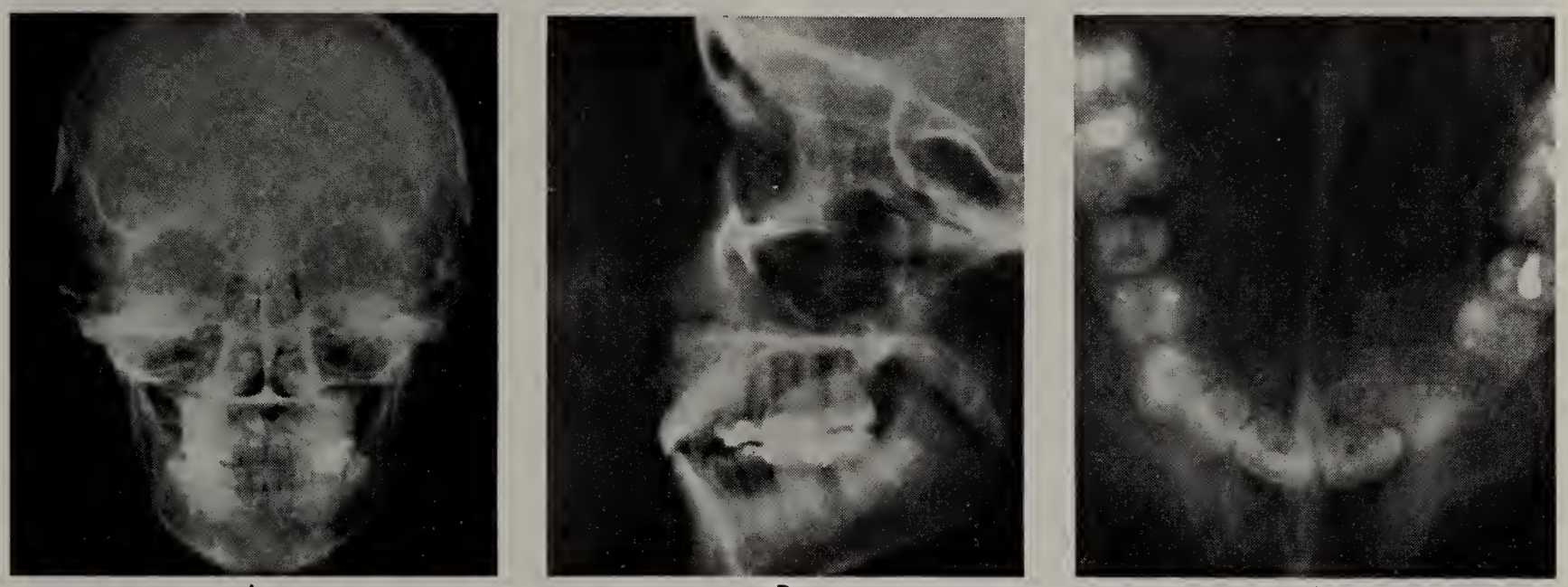
Further diagrams derived from tracings of the relevant films may be seen in *Fig.* 7. The lateral skull diagram shows the outline of the canine tooth rather vertical and well on the palatal aspect of the central incisors, but the postero-anterior film shows the increased angulation of the canine tooth to the midsagittal plane, the line passing through the canine tooth extending just beyond the outer limit of the skull and cutting the supra-orbital plane at a distance from it. The canine tooth may be seen lying along the line of the arch with its apex in approximately the correct position within the alveolus and its crown extending in close association with the lingual aspects of the roots of the upper incisors.

4. Unallocated Group (*Table I*)

It is possible that cases will occur that do not fall easily into any of the three categories described; it may be that there is a continuous range of canines extending right from one extreme, for

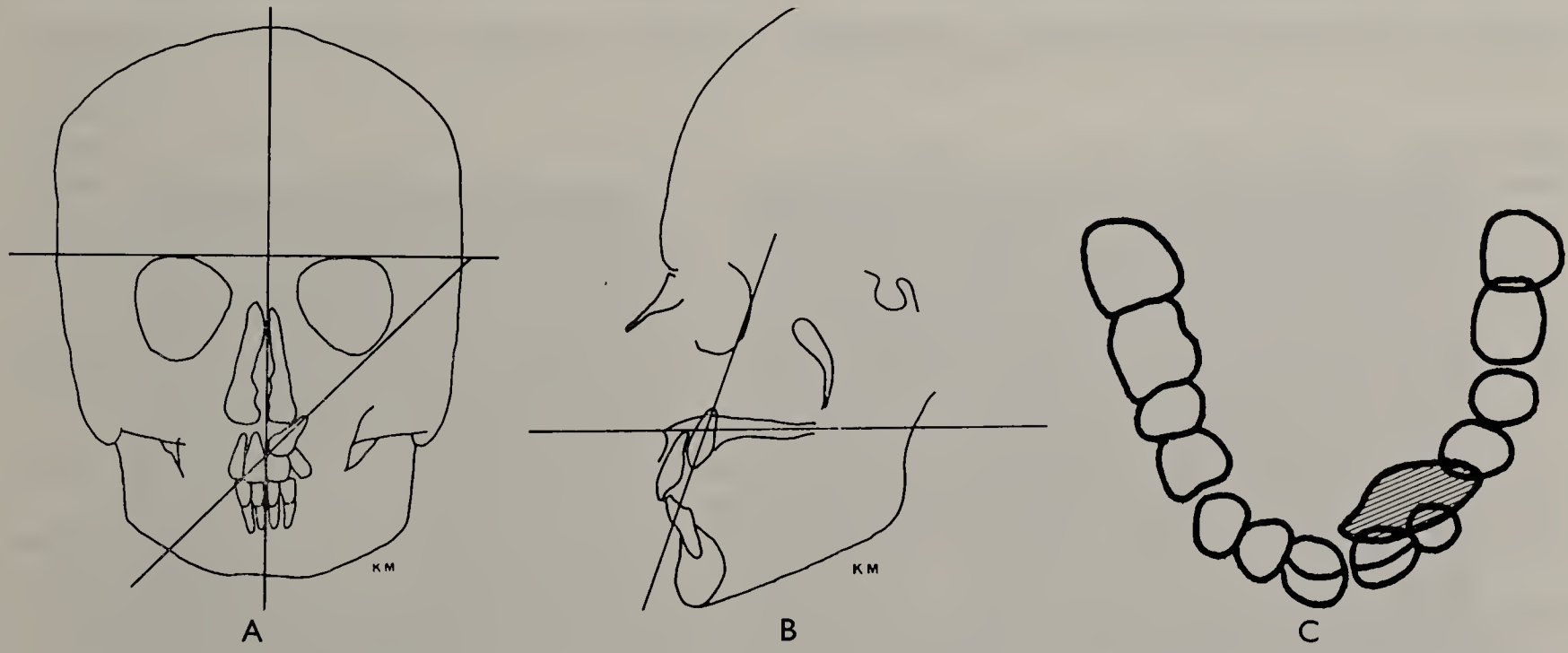
example, the horizontal group, through infinite variations to the other extreme, the vertical group. For various anatomical reasons it is felt that this is unlikely and at the present time 1 case is placed in the unallocated group and will have to remain rather inconveniently poised between two major groups.

were tabulated. This clarified the position and revealed that although a wide range of angular deviations existed only 2 cases approached the values found in the resorption group very closely and these were both of types belonging to the horizontal group. Although it is impossible to predict what would have been the outcome if the



A B C

Fig. 6.—A, Postero-anterior skull film in which marked inclination of the canine to the midline is apparent. B, Part of the lateral skull film in which the canine is foreshortened and inclined vertically. C, Vertex occlusal view in which $\underline{|3}$ may be seen passing obliquely almost behind the incisors.



A B C

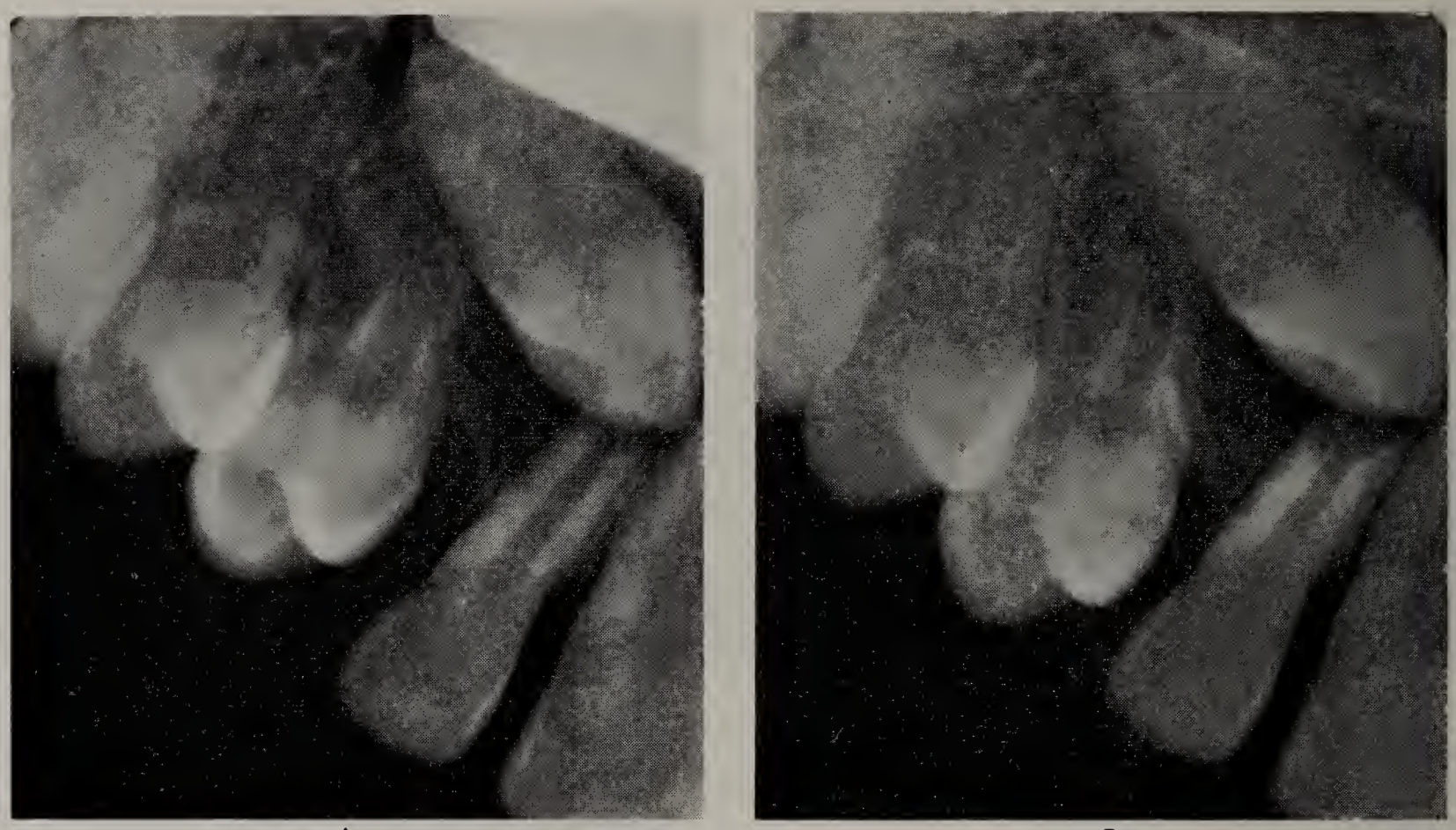
Fig. 7.—A, Postero-anterior skull tracing in which the canine inclination is somewhat between that of the two previous groups. B, Lateral skull tracing showing the vertical inclination of the canine in this plane. C, Vertex occlusal tracing showing the canine almost at right angles to the buccal segment.

Control Group

An examination of the lateral skull and postero-anterior skull films of the 45 control cases, i.e., cases having displaced maxillary canines but no incisor resorption, showed what appeared to be an even wider variation of canine position than in the resorption group. Tracings were made of all lateral skull and postero-anterior skull films and the angular measurements of the canine teeth to the maxillary plane and midsagittal plane

canine teeth in these 2 cases had not been removed it is possible that they may have gone on to cause incisor resorption if enough time had been allowed to elapse. The relationship found in the resorption group had not apparently yet been established in these 2 cases, although the angles were such that it was felt that a continued movement of the teeth along their long axes would have caused this relationship to be established in the fullness of time.

In all the other cases in the control group the angles and combination of angles were such that the crown of the displaced canine tooth was taken to a point where it was either not in close relationship to the incisor teeth, i.e., being displaced well palatally or well buccally, or, if it did form a close association with the incisor teeth, it was with the cervical or middle root thirds rather than with the apical root third. It should be emphasized that in the resorption group the canine tooth was so placed that its long axis passed through the site of the apex of the affected incisor tooth—a collision course of canine and incisor—and the resorption of the apex of the incisors appeared merely to facilitate the further eruptive attempts of the canine along its long axis.



A B

Fig. 8.—A, Intra-oral view of $\underline{2|}$ in an 11-year-old boy. B, Similar view taken 4 months later. Resorption of the root apex is now apparent.

Resorptive Process

Although it has been suggested in this study that proximity of the unerupted canine tooth to the incisor root is the most important factor in the initiation of the resorptive process, it should be understood that there is a considerable resorptive potential present in the permanent dentition that can become manifest after minimal or apparently no initiating stimulus.

Incidence of Resorption

Massler and Malone (1952) have shown that in an analysis of 13,000 teeth in 708 individuals 100 per cent of the individuals and 86·4 per cent of the permanent teeth demonstrated some degree of resorption. In only 5 per cent of the teeth was the reason for the resorption obvious. Admittedly the majority of these cases had mild resorption, but in 9 per cent classified as moderate the amount of resorption was 2–4 mm. of the root length, in 0·3 per cent classified as severe it was 4 mm. to one-quarter of the root length, and in 0·11 per cent classified as very severe the resorption amounted to more than one-quarter of the root of the tooth.

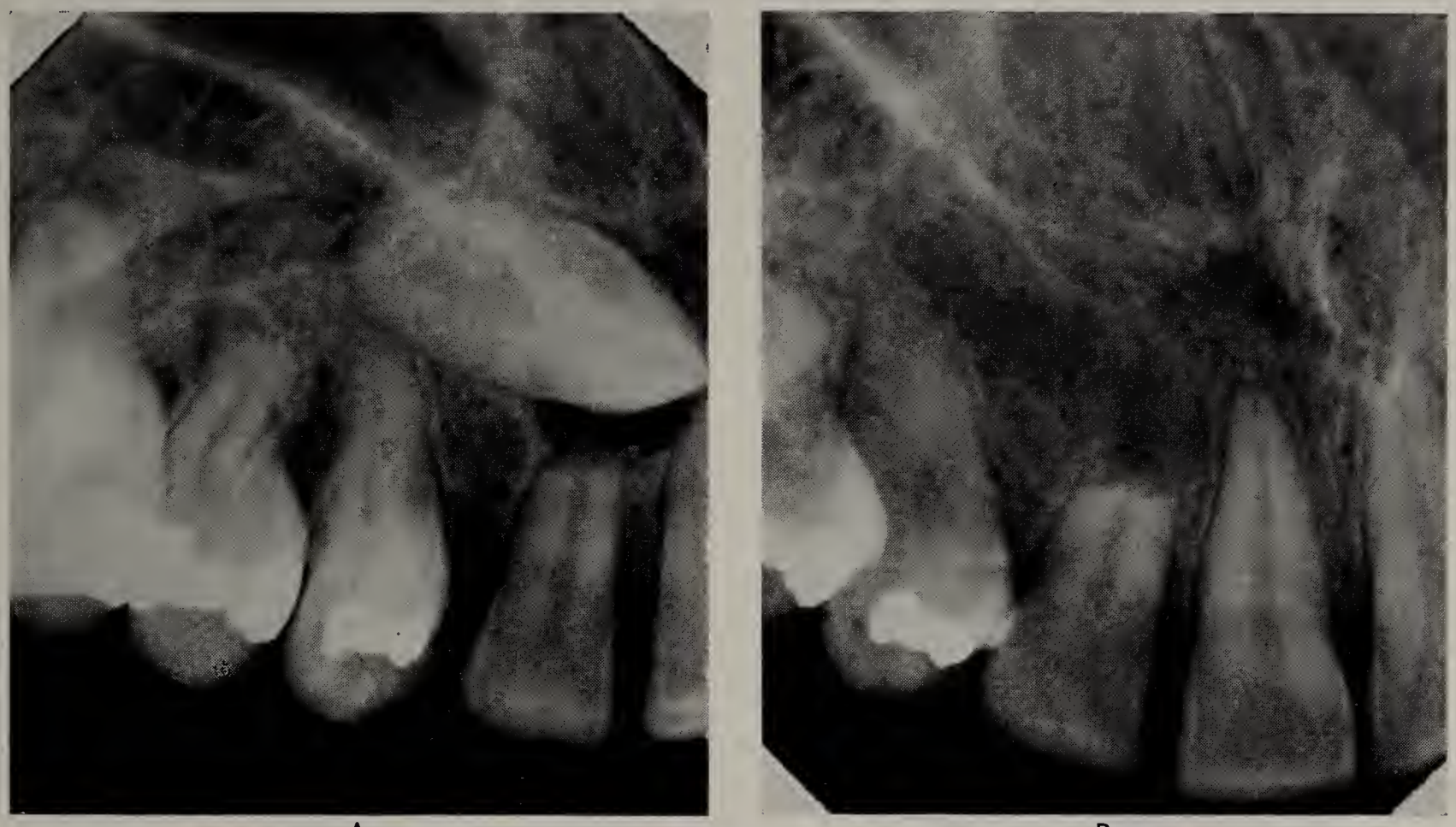
Anterior teeth appear to be more susceptible to resorption than posterior teeth. It is admitted by the authors that local factors, particularly orthodontic treatment and apical irritations, may greatly accelerate the spontaneous resorptive process.

In a later paper by the same authors (Massler and Malone, 1954) a further point seems to have emerged with regard to the susceptibility to resorption with age, there being a significant increase in the frequency of the more severe degrees of resorption with an increase in age. In the light of the latter finding it would appear to be unwise to leave a displaced canine tooth in close proximity to the root of an incisor since the likelihood of resorption will increase with age and perhaps be initiated at a later stage than might be expected.

Rate of Resorption

Little evidence seems to be available with regard to the rate of the resorptive process once started. It appears from clinical experience to be a rapid and progressive process unlike the

rather more leisurely stop-and-start resorptive process that one finds in the deciduous dentition. *Fig.* 8 shows the resorptive process affecting the upper right lateral incisor in a boy aged 11 years.



A B

Fig. 9.—A, Preoperative intra-oral view of $\underline{2}|$. Approximately one-third to one-half of the total root length has been resorbed. B, Postoperative view of $\underline{2}|$ showing arrest of the resorptive process and re-establishment of the lamina dura.

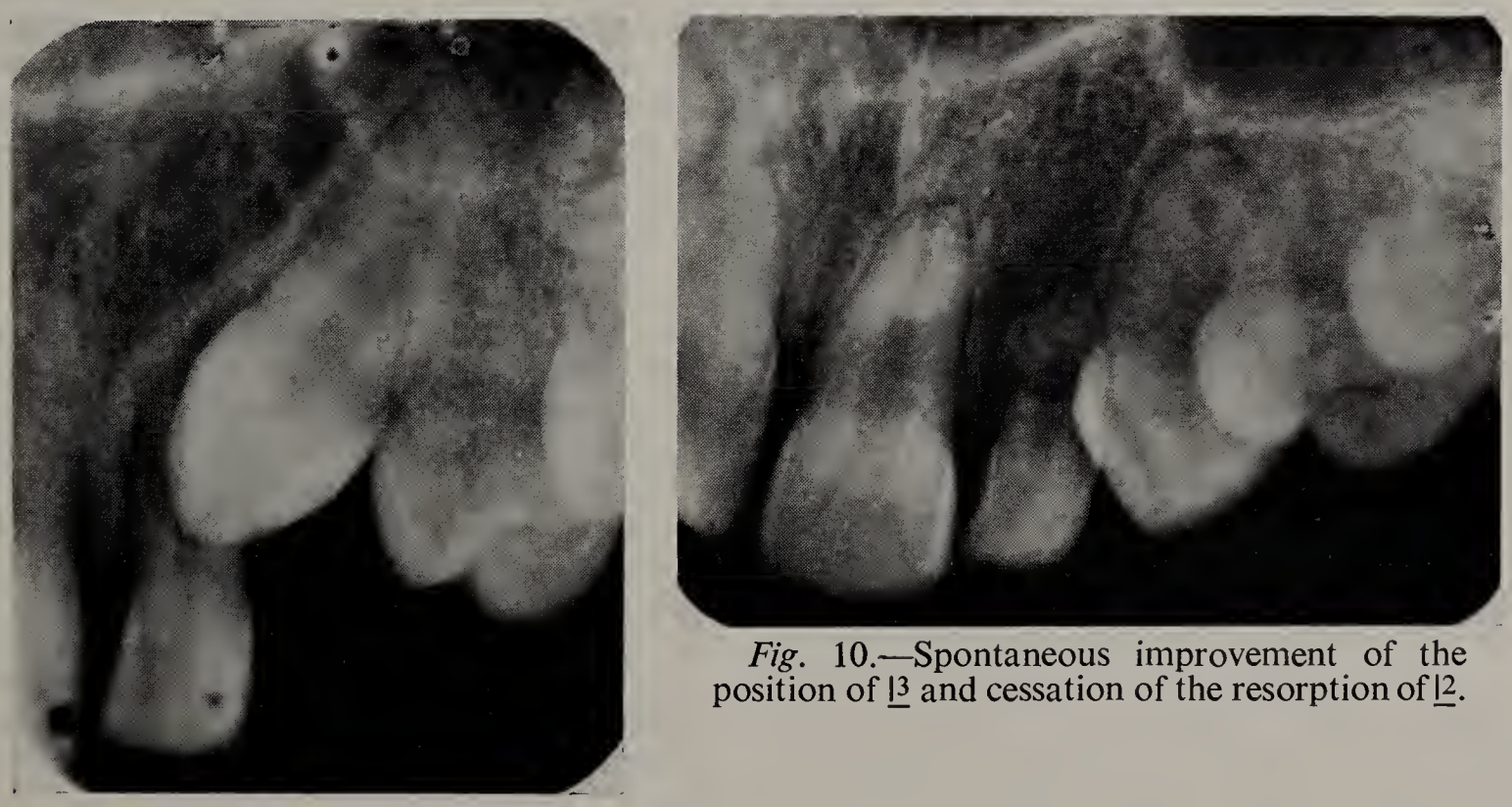


Fig. 10.—Spontaneous improvement of the position of $\underline{|3}$ and cessation of the resorption of $\underline{|2}$.

The time interval between the two films is 4 months.

Arrest of Resorption

It appears that when the initiating factor, i.e., the displaced canine tooth, is removed the resorptive process ceases and, provided that the incisor tooth root has not become shortened beyond the physical minimum necessary to withstand the stresses of mastication, a recuperative phase is entered and a new periodontal membrane is established around the new root contour (*Fig.* 9).

Very rarely this may occur owing to the spontaneous improvement in the canine position (*Fig.* 10).

CONCLUSIONS

It appears that there is a resorptive potential present in anterior teeth that increases with age and may be accelerated by apical irritation from various causes. It is likely that the presence of an unerupted tooth in close proximity to the apex of an incisor tooth may constitute such an

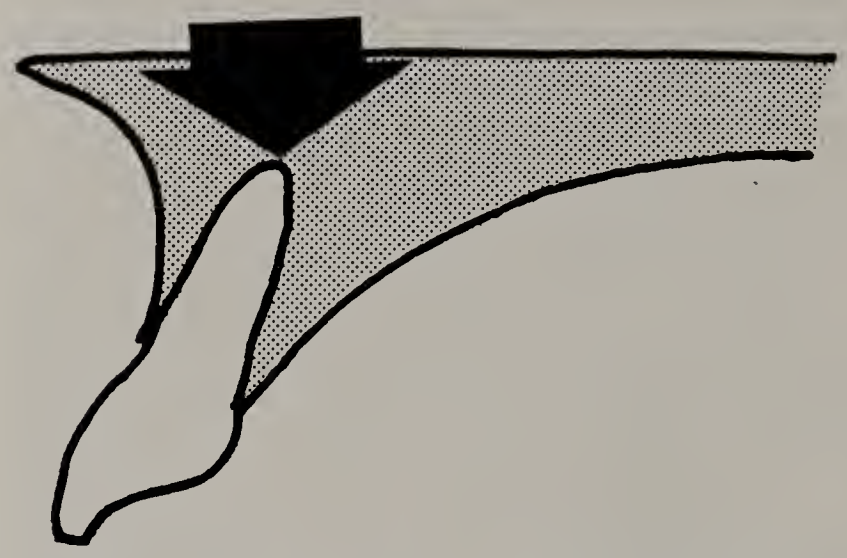


Fig. 11.—Vertical route by which the canine may become impacted.

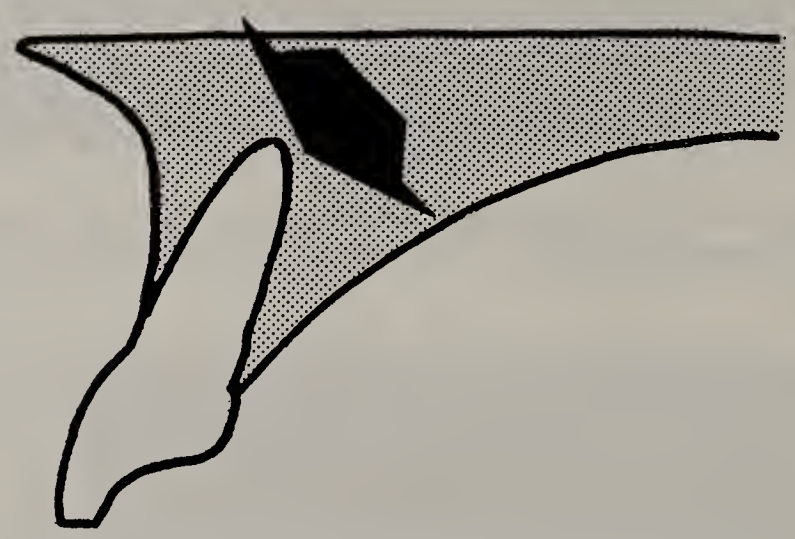


Fig. 13.—Lateral-horizontal route, by which the canine may become impacted.

irritation. In what is admittedly a small series of cases it has been found that a pattern has emerged with regard to the type of displaced canine tooth that appears to be likely to cause resorption. There appear to be three basic types. The division between types appears to be due to the anatomy of the parts concerned and simple geometry.

It has been suggested that not only does it seem necessary for the displaced canine to form a close relationship with the incisor root for resorption to occur but also that the relationship must be with the apex or apical third of the incisor root. It also appears that a genuine impaction must become established, i.e., it must be impossible for further movement along the long axis of the displaced tooth to take place owing to a physical obstruction, such as the incisor root. The displaced canine tooth may reach this position of impaction by one of three routes.

1. Vertical Route (*Fig.* 11)

By passing downwards from a position above the apices of incisors the canine tooth appears to be in a relatively vertical position in relation to the midsagittal plane and at the same angle, or only slightly different, as the angle of the maxillary incisors.

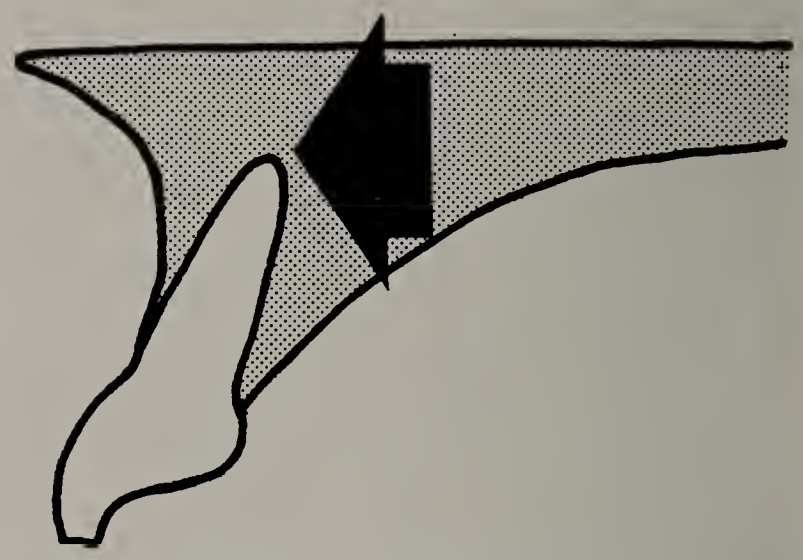


Fig. 12.—Horizontal route by which the canine may become impacted.

This situation could perhaps in other circumstances cause transposition of the canine if it passed mesially to the lateral incisor or impaction of the canine within the arch if it passed distally.

2. Horizontal Route (*Fig.* 12)

In this case the canine tooth lies horizontally within the alveolar bone or nearly so and passes forwards and may emerge from the alveolus either side or above the root of the lateral incisor. The angle of the canine tooth to the midsagittal plane may be variable. The higher the angle, the more mesially the canine crown will be found; the lower the angle, the more distally the canine crown will be found and usually the higher within the maxilla.

3. Lateral-horizontal Route (*Fig.* 13)

In this category the canine tooth is passing not from immediately above the incisor downwards or from the palatal side forwards but around the arch from the region of the canine on the palatal side of the roots of the incisor teeth towards the midline.

It is possible that some intermediate types between the three main groups will occur, as has been found in this study, but it appears likely that most cases will fall into these simple categories described since the anatomy of the maxilla provides these three routes of access for the canine tooth to reach the roots of the incisors.

Acknowledgements

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THE EVOLUTION OF THE FIXED APPLIANCE IN ORTHODONTIC PRACTICE

D. A. DIXON, F.D.S., D.D.O., M.D.S.

Sunderland General Hospital

INTRODUCTION

THERE is a danger at the present time, especially with some of the more recent approaches in fixed-appliance technique, that a student may gain the impression that this is a completely new departure from previous methods. Experience eventually reveals that almost every approach has been considered previously and that much valuable knowledge can be gained by studying the efforts of orthodontists in the past. At this time in this country many men are extending their use of fixed appliances and it is my hope that a short historical review may prove helpful in their evaluation of the capabilities of the various techniques currently popular. An outline of current techniques and attitudes in this field may also be of use to general practitioners and men practising in other dental specialities with little contact with orthodontic practice.

EARLY ORTHODONTIC APPLIANCES

As with many aspects of dentistry, Fauchard (1746) gives us a good introduction to early forms of orthodontic appliances. His book illustrates short flexible strips of gold or silver (bandelettes) which were tied to the teeth with waxed threads. Traction could then be applied through these early expansion arches to irregular teeth to bring them into alinement, but one hesitates whether to regard such devices as fixed or removable appliances. In the mid-eighteenth century France was a centre for advanced dental work and Bourdet (1757) comments that the strips should be of gold instead of silver, which turned black in the mouth. He also improved the attachment of the ligatures and produced longer buccal and lingual strips (*Fig.* 1). The extraction of the first premolars was recommended in cases of crowding to improve the prospects of obtaining a regular alinement. Both these orthodontic pioneers advocated tooth transplantation and surgical correction of tooth position when the patient could withstand such procedures.

Progress continued to be made on these lines and extensions appeared at the ends of the strips grasping the molars (*Fig.* 1), thus improving the stability and giving the appliance a more familiar form. From the earliest days wooden or ivory blocks (Fox blocks) were used to open the bite and forms of inclined planes were constructed. The invention of vulcanized rubber and its use in dentistry from 1854 revolutionized the process of making appliances of all kinds for the mouth. Prolonged disputes over patients delayed the widespread clinical introduction of this material for some time, but by 1904 Jackson could publish a volume showing a remarkably modern-looking series of removable orthodontic appliances supported by his well-known crib.

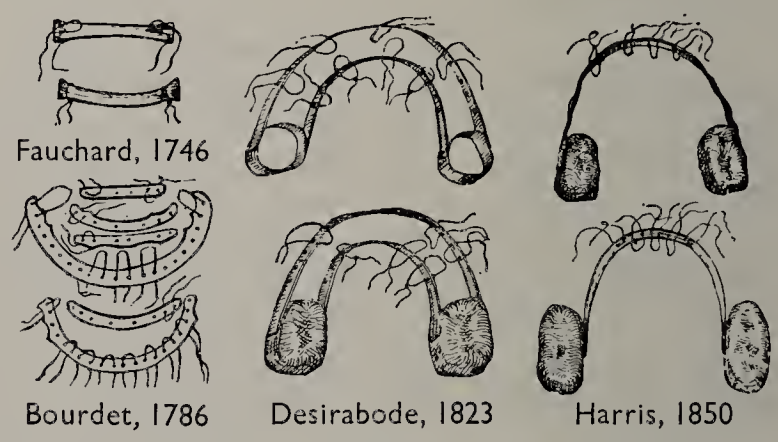


Fig. 1.—Early orthodontic fixed appliances (*after Farrer*, 1888).

For a period such removable appliances were more stable than appliances relying on waxed threads. In the late nineteenth century America provided a rich vein of progress in orthodontics. A number of American dentists had received training in Paris and returning to the United States at a period of rapid industrial progress and wealth were able to put these methods into practice and make many advances. Clamp bands provided stability and allowed labial arches to be attached. The main dispute of the time was between the advocates of rapid movement with the screw and those using a slower correction with the ligature or spring. The great variety of appliances and great expertise of individual operators are well illustrated in the two volumes on orthodontics by Farrar (1888) which even now

Presented at the Meeting held in Aberdeen on 23 October, 1970.

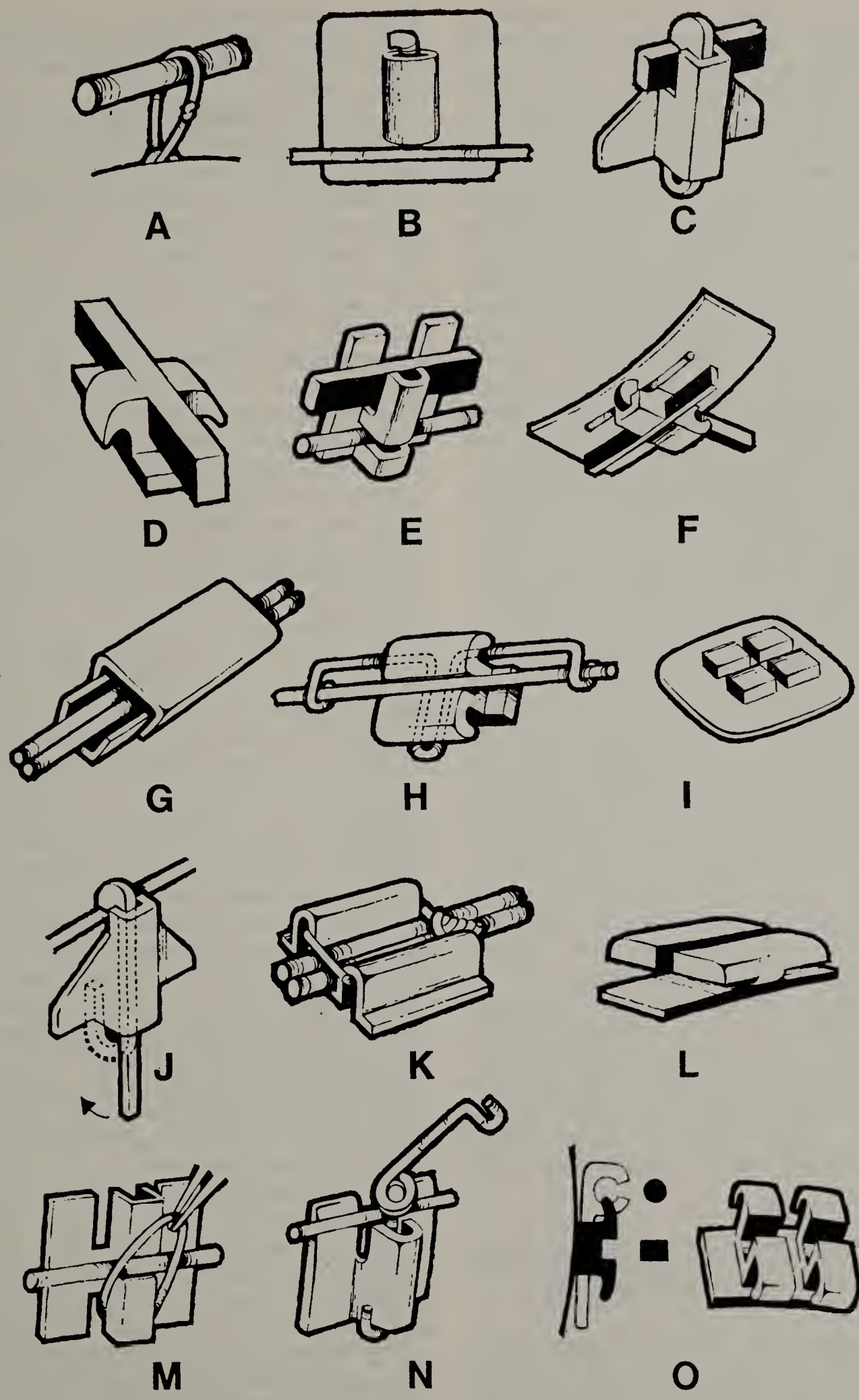


Fig. 2.—Orthodontic brackets. A, Direct ligature of ' E ' rigid arch to eyelet on tailored band. B, Pin and tube (Angle). C, Ribbon arch and bracket with pin fixation (Angle). D, Edgewise bracket and rectilinear wire arch (Angle). E, Universal bracket for light ribbon arch and round wire (Atkinson). F, Combination bracket for both light wire and edgewise arches (Begg-Chun). G, Friction-lock bracket and twin-wire arch (Johnson). H, Modified edgewise bracket with vertical slot for T-spring auxiliary (Broussard). I, Plastic direct adhesion bracket. J, Unipoint bracket and pin for light wire (Begg). K, Ripple bracket for twin and single round wire (Townend). L, Edgewise bracket for light wires (Jarabak). M, Light wire simplex bracket for Alastik-ring fixation. N, Long flange bracket for light wire with root-paralleling spring. O, Combination light wire and siamesed edgewise bracket with specialized pin with round wire channel (Fogel-Magill).

are still worthy of study. Even rapid expansion of the maxilla and root movement of individual teeth were attempted in this era.

The individual tailored band was introduced in platinum in 1871, and the development of oxyphosphate cement at this time allowed such bands to be cemented. Therefore the truly fixed appliance evolved gradually, but this did not prevent a remarkable number of applications being developed with delicate appliances in fine gold. Elastic traction was extensively used from 1850 but was often rejected as it is now owing to unfavourable movements of anchor teeth. However, when elastics were used for intermaxillary traction (Baker anchorage) this widened the sphere of orthodontics into facial aesthetics by correction of the mal-relationships between the arches rather than just individual tooth corrections. The great artist and clinician Norman Kingsley (1880) suggested the inclined plane in vulcanite for the same purpose and 'jumping the bite' became popular, while previously in 1850 he had suggested occipital traction for distal movement of the upper arch.

Fixed levers or whips were also introduced by Nutting Farrar, who also refined the fixed screw and introduced appliances for incisor root movement and eventually became involved in disputes as to the originality of these and other devices with the young but vocal orthodontist, Edward Angle. The situation at this time was commented on acidly by Clark (1887) in New York to the effect that Dr. Farrar with his complicated network of springs and pulleys appears to have no failures, while Dr Talbot with piano wire is equally successful. Dr. Kingsley who ignores and condemns both is always right, but Dr. Jackson who apparently does all with split plates speaks of but one failure. Dr. Clark then suggested that this was not the impression gained by one who had these patients to treat subsequently, and these strictures on the disputes between the advocates of the various techniques then available might well be applicable to the present time.

THE DEVELOPMENT OF ORTHODONTIC BRACKETS AND PHILOSOPHIES OF TREATMENT

With the appearance of Angle (1907) orthodontics became a speciality, as he encouraged men to limit their practice in this subject, while previously orthodontics had been undertaken by men in the highest class of general practice. He sponsored German silver appliances which allowed a system of orthodontic components to be offered commercially at an acceptable price to the profession. Removable appliances were eventually completely discarded by him owing to their relative inefficiency at that time. He developed a system of fixed appliances capable of correcting the teeth to a so-called ideal arch form using intermaxillary traction to correct the occlusion by forward movement of the lower arch.

Angle first advocated the 'E' (for expansion) arch which was constructed from a heavy, round, German, silver wire, with screw-activated nuts, by which the arch could be advanced in molar tubes and the arch size enlarged in all dimensions. The teeth were alined to the arch by waxed thread or wire ligatures engaged in notches on the arch (*Fig.* 2A). Even now these appliances can still be seen very occasionally in practice, especially in patients coming from Far Eastern countries. At around 1910 Angle was influenced by a misinterpretation of Wolff's Law of Bone (1892) and the famous Hunning case (Brodie, 1950), and from then on he began his attempts to control the angulation of the teeth more exactly and thus, he thought, to grow bone. New gold alloys allowed Angle to introduce the pin and tube technique in 1912 for root movements but this proved to be beyond the capabilities of most men technically (*Fig.* 2B).

As one of the first advocates of the use of the drawn tube in orthodontics Angle's mind naturally turned first to this possibility, and therefore the pin and tube cannot be considered as the first true bracket. This most important step came in 1920 with the ribbon arch and slotted bracket (*Fig.* 2C) and the almost equally important pin fixation of the arch. Although termed a ribbon in reality this was an archwire with quite a thick cross-section, and again theory outdistanced practice and tooth pressures were high and control proved difficult, especially in the premolar region. Angle thereupon placed this arch edgewise on into a horizontal slotted bracket (*Fig.* 2D), and the edgewise appliance was produced in 1928. This 'latest and best in orthodontic technique' as he called it allowed a very exact control of the tooth position in all its relationships, and the prediction of the ideal arch form without always the consideration of the individual morphology of the patient became a fashionable study.

It must not be thought that the American orthodontic scene consisted only of Angle. Possibly the greatest all-round clinician and orthodontist was Calvin Case (1921), who not only disputed in famous dialogues with Angle on his non-extraction doctrine but was also a technician of the very highest order. At the beginning of this century he could undertake root movement using two archwires and was one of the first people to use a light round wire for gentle tooth movements (Yudelson, 1967), although the poor properties of the German silver and gold wires at this time rendered such attempts difficult.

In the 1930's the danger of heavy forces in orthodontic treatment was brought to the notice of the profession by animal experimentation by

Oppenheim (1911) and other German *émigrés* in America; also Ketcham (1926) showed clinically that orthodontic treatment with the heavy forces applied by the fixed appliances of the time could cause root resorption. Appliance systems were then introduced allowing the use of light forces in orthodontics and occipital traction was reintroduced. One of the instructors in Angle's school was Spenser Atkinson (1937), and from him came the universal appliance and bracket utilizing a light ribbon arch (*Fig.* 2E) to control individual tooth movements in the three planes of space, and fine round wires to give the optimum control and pressure for the tooth movement. Johnson (1934) then introduced the twin-wire arch in which two fine round wires (*Fig.* 2G) enclosed in buccal tubes are used to the optimum effect in correcting multiple incisor rotations, for which it still cannot be bettered.

An alternative gentle approach was developed by Mershon (1920), who introduced the removable lingual arch with gold auxiliary springs. This also allowed light pressures to produce a considerable range of tooth movements, especially when combined with the high labial arch introduced by Lowrie (1928) which has remained popular as it is inconspicuous. The historical aspects of orthodontics up to this date are extensively documented by Weinburger (1926).

An expansionist and non-extraction approach was still aimed for by exponents of these appliance systems. The implication by Angle that relapses were caused by insufficient skill in building the arch form inhibited many from revealing their compromises and failures. Retention procedures were a vital part of treatment both in fixed and removable forms, as with the design of Hawley (1919). Although Angle would privately admit there might be cases in which a reduction in tooth tissue was mandatory he felt that it was unwise to teach such compromises. His disciples, as always, were far more extreme in attitude and Lowe Young, a great exponent of the Angle appliances, was an example. He is quoted by Porter (1947) as stating in discussion of a paper by Dr. Case: ' I have greatly enjoyed your paper but want this audience to know that you have done more harm today (by advocating occasional extractions) than you have ever done good in your whole life '. The apex of the Angle philosophy was similarly presented in Strang's (1933) *A Textbook of Orthodontia* in which the possibility of extractions is not discussed. It does contain, however, an excellent historical section.

THE BRITISH CONTRIBUTION TO FIXED APPLIANCES

There appears always to have been a bias in this country towards the simple approach and the use of the removable appliance and therefore this cannot be attributed to present-day expediency. Colyer (1900) illustrates many useful removable appliances, and split-plate designs using piano wire in the form of U springs called after the Coffins, two American dentists, father and son, both practising in London at the end of the nineteenth century, were popular for a long period. Early forms of orthodontic treatment including inclined planes were mentioned by Hunter (1771), the great English surgeon and anatomist of the eighteenth century. He did not despise earning the ' damned guinea ' as he termed it by advising on replanting teeth and other dental procedures.

The first clinician to be appointed to teach solely orthodontics was Chapman at the London Dental School, and the chapters by him on orthodontics in Bennett's (1931) text, *The Science and Practice of Dental Surgery* are still notable, as are his reminiscences (Chapman, 1954, 1956). Both Chapman and Friel attended the School of Angle, and Friel in Dublin became the first man in the British Isles to limit his practice to orthodontics. The American orthodontic developments were followed but applied in a modified fashion as the prolonged treatments required for the non-extraction approach could seldom, fortunately, be applied in British practice.

The advance of stainless-steel technology in dentistry is tied closely to the industrial application and development of this material. The first all-steel-bodied car, the 1914 Dodge, was designed by the Budd Company of Philadelphia. As gas welding was found to be not entirely suitable for this application, arc welding was developed by J. W. Meadowcroft, an English Employee of the same company. A visit by W. R. Morris (later Lord Nuffield) eventually resulted in the setting up of the Pressed Steel Company of Cowley (Hendry, 1970). Previously, however, André Citroen of France had obtained the rights of the Budd patents in 1924 and he introduced all-steel-bodied cars into the continent including the remarkably long-lived, front-wheel-drive, prewar Citroens. It is therefore not surprising that the introduction of stainless steel into orthodontics was by Da Costa in France. This major advance in technique was taken up in Britain by Friel (1933), who improvised a method of constructing molar bands from welded strips of the material which is still in use today. He also showed how removable lingual arches and auxiliary springs could be constructed from stainless steel in delightful ways which many of us treasure as our training exercises.

Stainless steel was cheap but remarkably strong with many good features, but one problem which prevented its widespread application at that time was that only cumbersome welders were available. Watkin in Liverpool, who had originally trained as an engineer, in spite of some initial reservations about the material, also took up its application and developed a relatively

mobile welder which greatly facilitated the application of the technique clinically. He also introduced (Watkin, 1933) the remarkable loop-and-tube appliance which in capable hands could bodily retract the upper incisors with very little loss of anchorage, and also can still be advantageously utilized in many sectional forms for local tooth movements.

Directly after the Second World War the twin-wire arch was introduced into this country by Townend (1948), who adapted its construction to the stainless steel available and introduced the ripple bracket (*Fig.* 2K) which could also be constructed from stainless-steel tape. In this form the appliance was used widely in this country, especially in cases of marked incisor imbrication, and is still in routine use. In an attempt to improve the finish of cases using a simple approach and the ripple bracket a round-wire arch system with vertical loops was developed by Hill (1954) of the London Eastman Dental School. These two approaches with the various labiolingual applications previously described comprised British orthodontic fixed-appliance therapy until recently. This outline of the development of fixed appliances in this country is necessarily sketchy and incomplete. As there are others better qualified than I to record this type of material perhaps it could be time to form a historical section of this Society.

In the provision of orthodontic treatment for the community since the inception of the Health Service in 1946 it has been found that an extractionist policy, when based on sound diagnostic and biological principles will allow a spontaneous resolution of many cases of irregularity (Ballard, 1971). The treatment of the majority of cases requiring active treatment can be satisfactorily accomplished by a system of efficient but simple removable appliances after designs by Adams (1955) and many others. Complex tooth movements are required only in a minority of cases and then appropriate fixed appliances can be utilized, often in the form of local sectional techniques (Hooper, 1964). This approach has allowed 1 in 4 children to receive some form of orthodontic treatment under the British National Health Service (Godber, 1968), which approximates closely to the observed level of need in the community (Tulley, 1964).

RECENT DEVELOPMENTS IN THEORY AND PRACTICE

Between 1940 and 1950 our American orthodontic colleagues adopted stainless steel for fixed techniques, but found it necessary for patient acceptance to rename it temporarily chrome alloy. A more fundamental change resulted from studies with the then new cephalometric method, which revealed that the results of treatment with fixed appliances and intermaxillary traction were limited to tooth movements within the alveolar process. This appeared to confirm the concept of Lundstrom (1925) of an immutable dental base, and the limitations of orthodontic treatment put forward by Nance (1947).

The men trained by Angle were rescued from this dilemma by a new diagnostic method and approach with the edgewise appliance from Tweed (1953). This was based on an ideal and stable positioning of the lower incisors in a maxillofacial triangle and the routine 4 bicuspid extraction case became an acceptable clinical approach in a remarkable change of attitudes. Unfortunately the concept of a 'norm' in facial form to be aimed at by the clinician was also born at the same time. It must be mentioned that these restrictive views on the potential of orthodontic corrections were never accepted by Continental orthodontists (Hausser, 1969), who maintain that permanent change in jaw relationships could be achieved by functional techniques, at which they excel. Whether there could be a variation in response with individual morphological types may be better defined in the future.

In Great Britain in the post-war period an extensive researching of the oromuscular environment by Rix, Ballard, Tulley, and many others resulted in the concept that orthodontic treatment should be restricted to corrections within a dominant and largely unchangeable inherited soft-tissue form. Recently the observations of Mills (1968) on the very limited changes in position of the lower incisors brought about by treatment have appeared to confirm such an attitude. Generally it may be said that stability after treatment is an essential aim in British orthodontics and the use of a canine-to-canine fixed retainer is regarded with suspicion. Experimental evidence, however, using strain-gauge and other techniques consistently refuses to support the concept that the teeth are in balance between the lips and tongue either in the incisor region (Gould and Picton, 1962) or in the buccal segments (Dixon, 1959), and a further breakthrough in experimental technique may be required to clarify the situation.

At the present time the anatomical concept of a functional matrix (Moss, 1962), and the remarkable clinical achievements of Fraenkel (1966, 1970) using functional appliances designed to change the muscular environment of the occlusion may represent a reverse trend. In the fixed-appliance field also the progressive approach (Ricketts and Hilgers, 1972) now offers a computerized forecast of adult facial form, and the necessity at times to consider retention after active treatment until the maturation of the soft tissue and skeletal form of the child maintains the correction. If this allows the individuality of each patient to be truly expressed it will be a major advance in diagnostic technique, but it is doubtful if clinical experience

can ever be completely surplanted as there is always the exceptional patient.

Generally there is a revival of interest in the possibility of orthodontic treatment improving total facial form. Criticism is heard of radical extraction approaches on the grounds that clinically an excessively concave profile or ' dish-face ' can result and the matter has not as yet been resolved by cephalometric study of the profile (Hershey, 1972). In such times of controversy a reasonably balanced view can only be obtained by considering the subject in historical perspective. Eventually stereophotogrametry techniques may allow the effects of orthodontic treatment on the total facial integument to be assessed in a less subjective manner.

Comment must be made on the light-wire differential force approach (Begg, 1956, 1961) which has greatly invigorated current fixed-appliance technique. Historically this technique is interesting as Begg originally used Angle's ribbon-arch bracket (*Fig.* 2J) but with a light round arch and a markedly extractionist policy supported by observations of attritional loss of tooth tissue in the Australian aborigine. One remembers that Angle's expansionist doctrine was partly based on the occlusal form of ' Old Glory ', a negroid skull, and such observations on ethnic groups other than those under treatment will always be suspect.

The most valuable bite-opening and rapid corrective movements obtained in the early phases of the Begg treatment were revolutionary. Such a wide range of tooth movement was made possible by the development in Australia of a very high-tensile wire and by the long-ignored low-friction advantages of pin fixation. Many converts were made throughout the world to fixed appliances but they found that the Begg man must be courageous as each stage of the treatment requires precise judgement of anchorage and a most co-operative patient. The many problems are described by Parker (1969) and it is no longer felt generally that this technique is a short cut to a high-volume practice in fixed appliances. However, the concept of a third or finishing treatment stage in which all tooth contacts are regularized and root angulations are corrected with incisor-torquing and root-paralleling auxiliaries, if necessary (*Fig.* 3) is now mandatory for all methods which aspire to the designation of a precision technique.

The edgewise appliance has in the meantime remained the dominant appliance in North America. A conservative approach to extraction is still common but the appliance also has been remarkably adapted by many clinicians to an extraction approach. The major part of treatment is now usually carried out with light round wires; not a new approach as Hawley (1925) described the preliminary use of a round wire when using a ribbon-arch technique. Vertical loop arches, as with the Stoner (1960) and Jarabak (1960) systems, are one approach to avoid the high frictional resistance of the horizontal bracket. The ' crowbar ' of old has disappeared and auxiliary springs (*Fig.* 2H) with modified or siamesed brackets are used, while light round wires are preferred initially for bite opening and simple movements. The finishing of cases by the use of rectangular wire is still unexcelled in the best hands (*Fig.* 4) but unfortunately the technique is time consuming and this is reflected in less than 1 in 20 children receiving orthodontic treatment in the other English-speaking countries which follow this approach (U.S.A.: 4 per cent treatment level with over 5000 orthodonticts (Brophy, 1971); Australia: 2 per cent treatment level (McKinnon, 1964); Canada 1–4 per cent with over 150 certificated orthodontists (Vasiga, 1970)). There is obviously need of a middle ground where the children of the community are covered, as in the British situation, but an element of high-quality treatment is available as elsewhere.



Fig. 3.—Root paralleling $\underline{|3}$ by auxiliary spring with the Begg-type light round wire appliance (*Mr. G. H. Roberts*).



Fig. 4.—Modern edgewise treatment with rectangular wire (*Dr. J. D. Atherton*).

From a purely technical viewpoint it may be said that the distinction between an idealistic level of orthodontic care and otherwise is not now defined by the use of fixed or removable appliances. It is by the production of a finished case with all the tooth angulations and contacts regularized and the occlusion levelled, usually with a multiband precision type appliance; as against a so-called compromise treatment with either simple fixed, or removable appliances. The term ' compromise treatment ' ought not



Fig. 5.—A versatile approach with universal appliance components.

to be considered derogatory, as from the biological standpoint the advantages of each approach have yet to be resolved; perhaps ' combined therapy ' would be a better term, indicating that it may be in many cases the best approach. The advantages of simplicity of technique and a short treatment time are considerable in patients with less than ideal tooth quality or dental consciousness. Every patient should be considered as an individual and fine finishing in the buccal segments should be undertaken as an elective procedure and not just as an exercise in technical expertise governed by adherence to a rigid technical approach.

The desire to use several archwires of markedly different characteristics during treatment procedures appears to be increasing. Ever heavier third stage arches or even dual wires (Haynes, 1968) are used in the Begg system to overcome finishing problems with this technique, and exponents of the Ricketts approach now manage to accommodate both a round wire and a square wire in a modified edgewise bracket. There is an interesting development in the so-called ' combination ' brackets of which the Begg-Chun (*Fig.* 2F) was an early example accommodating both round and edgewise arches with pin fixation. A recent introduction is the Fogel-Magill (1969) bracket (*Fig.* 2O) with both a bundle arch and an edgewise arch with pin fixation. Some consider that the Atkinson Universal system (*Fig.* 5) is still the best design in this field as it allows the use of both very light round wires for gentle tooth movement and also precision finishing with a ribbon arch. Such approaches are designed to avoid the marked frictional disadvantages of the horizontal bracket, with binding preventing tooth movements along the archwire (Nicolls, 1968), and yet to retain optimum control for precision alinement of the teeth.

There are indications that in some quarters in all countries thought is being given to combining the advantages of the removable and the fixed-appliance systems. In the U.S.A. there is a tendency away from the previously inevitable ' full-strap up ', as even the American patient can show a resistance to banding (Moyers, 1964). Recently an excellent article on the advantages of retracting upper canines with removable techniques (Lewis, 1970) has appeared in the American orthodontic literature, while on this side of the Atlantic, fixed attachments to removable systems are being developed (Hasund, 1969).

At present many tooth movements cannot be efficiently carried out without sophisticated fixed techniques (Moyers, 1964). It may be hoped, however, that eventually a high level of treatment will be attained without a crystallization of clinicians in this country into exclusive adherents of specific fixed-appliance systems, as has occurred in North America. Such exclusive groupings and study clubs making a cult of their individual bracket tend to discourage methods and advances outside of their own system. All appliances should be the servant of the clinician and never the master, and an integrated approach to orthodontic treatment using the best features of some of the currently available fixed and removable techniques is well presented by Usiskin and Webb (1971). An ever-present danger is that with the delights of the sophisticated fixed techniques one can forget that the primary object is the improvement of dental health of the community, and also that enamel and periodontal lesions are an unacceptable penalty of orthodontics.

A rapidly advancing technological field which has a direct impact on fixed orthodontic technique is that of methods of cementation. The British discovery of carboxylate cements (Smith, 1968) has come nearly a century after the similar introduction of oxyphosphate cements. It was some 50 years after oxyphosphates were available that cementation of all bands became universal. It may be as long before the full potential of the new cements and the future biological adhesives are integrated fully with clinical orthodontic technique. Remarkable progress has already been made and direct attachment of brackets to teeth is now possible in limited clinical applications (Mizrahi and Smith, 1971). At the same time the introduction of plastic materials in bracket design and even plastic substitutes for springs and elastics (*Fig.* 2I, M) suggests that in the future one may view the present multiband

systems as just an evolutionary phase in the progress towards an efficient, yet biologically acceptable, orthodontic technique.

An orthodontist looking to the future must now prepare for attacks on the fixed-appliance banding procedure by periodontologists. It can justifiably be claimed that orthodontics improves dental health by patient education and orientation to a proper state of dental consciousness, while it has been conclusively shown (Hoover and Lefkowitz, 1965) that periodontal disease is directly related to oral hygiene and that this is the greatest single cause of tooth loss in middle age. Therefore orthodontists should plan their treatment programme and appliance technology to minimize this problem. A further argument that can be put forward is that irregular teeth are prone to food impaction, and thus, both gingival involvement and carious attack are reduced by orthodontic treatment, although, to date, cross-sectional studies have disappointingly shown little relationship between tooth irregularities and periodontal conditions (Beagrie and James, 1964), or even depth of overbite (Alexander and Tipnis, (1970). However, there can be no doubt that many individual cases can be demonstrated in which gingival stripping is reduced by correcting tooth tilting and traumatic tooth positions, and orthodontic patients have been shown to have a reduced rate of tooth loss subsequently (Campbell Wilson, 1969).

I would wish to see all orthodontic clinical case reports accompanied by periodontal assessments both before and after the treatment (Dixon, 1968); also orthodontic texts could cover this aspect more completely with advantage. This might reassure the periodontologists that the orthodontist is properly concerned with the dental health of his patient in later life. This is particularly important at a time when it is increasingly believed that many periodontal conditions can often be traced to a breakdown of gingival tissues in early childhood (Fish, 1961), and it is only reasonable to consider whether bands disturb the epithelial coll area to some extent. Comparison of the adult oral state of patients with malocclusions previously corrected by both extraction and simple treatment methods with that after treatment by precision multiband techniques would be most valuable. Such information would allow progress in orthodontic appliance design to be governed by biological requirements, and it is hoped that university departments of preventative dentistry will undertake such studies as an urgent requirement for the evolution of scientifically based systems of orthodontic treatment for the community.

SUMMARY

1. Fixed orthodontic appliances are still in a state of rapid evolution and radical changes can be expected with advancing technology.

2. Clinicians should keep an open mind and refrain from becoming complete adherents of any single appliance system and philosophy of treatment.

3. A continuing interest should be maintained in the biological aspects of orthodontic appliance therapy, and in particular its relationship to lasting dental health.

4. One can be proud of the British contribution to the development of fixed appliances and the application of orthodontic treatment as a public health measure.

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ORTHODONTIC TOOTH MOVEMENT USING A MULTIBAND TECHNIQUE RECORDED BY CINE-PHOTOGRAPHY

D. G. HUGGINS, B.D.S., F.D.S., D.Orth.

Dental Department, Chester Royal Infirmary

INTRODUCTION

AUDIO-VISUAL systems have been advocated as teaching aids and are being increasingly used in the medical and pharmaceutical fields.

Tulley (1961) and Price (1969) have previously described this medium.

In order to demonstrate a method of multiband orthodontic treatment to students it is advantageous to simulate a malocclusion on a typodont which allows tooth movement to be accomplished over a period of hours rather than wait for biological processes to allow tooth movements in the mouth over a period of months. The use of this system has been well described by O'Meyer (1967) and MacCallum (1969).

MATERIALS AND METHODS

A 16-mm. cine-sound film was used in order to illustrate this technique. At the commencement the film shows instruments used in the management of fixed-appliances. A malocclusion with a Class III incisor relation where $\overline{4|4}$ have been extracted is used to demonstrate the technique (*Fig.* 1). Lateral skull radiographs and tracings indicate the Class III dental base relation and increased maxillary-mandibular-plane angle. The treatment plan involves alinement of palatally excluded $\underline{5|5}$ by distal movement of $\underline{6|6}$ and retraction of $\overline{3|3}$ so that $\overline{21|12}$ may be retroclined and $\underline{21|12}$ proclined in order to achieve a Class I incisor relation.

The selection of preformed bands and the welding of attachments is illustrated, followed by the cementation of bands in the correct position on the teeth. Arch formation using 0·4-mm. extra-hard stainless-steel wire is facilitated by using the Bonwill-Hawley Chart.

Inclusion in the arch of traction hooks to allow intermaxillary traction and closing loops for intramaxillary traction is described.

The method of moving $\overline{3|3}$ distally is illustrated using compressed coils on the arch tied back to $\overline{6|6}$ with 0·3-mm. soft wire.

The typodont is now shown with the arches ligated in order to move 6|6 distally and to aline $\underline{5|5}$, with anchorage being supported by intermaxillary traction; $\overline{3|3}$ are being retracted using compressed coils tied back to $\overline{6|6}$. The typodont is immersed in water at 50° C. and time-lapse photography is used to enable tooth movement



Fig. 1.—Model showing the malocclusion

to be demonstrated on a reasonable time scale (MacCallum, 1969). With $\overline{3|3}$ retracted and $\underline{5|5}$ alined the second lower arch is placed which has closing loops and traction hooks incorporated distal to $\overline{2|2}$. Class III intermaxillary traction is shown supporting lower arch anchorage, and with closing loops activated the $\overline{21|12}$ are retroclined and $\underline{21|12}$ proclined.

A Class I incisor relationship is achieved. A comparison of the occlusion before and after treatment concludes the sequence.

CONCLUSION

The advantage of the typodont as a teaching aid is recognized in many centres and this film was produced so that the student may be

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acquainted with the technique during a 15-minute showing. It is not intended to be comprehensive and must be supported by illustrations and demonstrations of the detailed application of the technique.

Acknowledgements

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DENTAL ATTRITION AND PRIMITIVE CORN MILLING

G. H. ROBERTS
Consultant Orthodontist, Royal Aberdeen Children's Hospital

DENTAL ATTRITION

Attrition of the human dentition has been a phenomenon of interest to many investigators both past and present. The condition causes the gradual wearing away of the teeth during masticatory function and concerns the dental specialities of orthodontics, periodontics, and forensic odontology. Outside the dental profession attrition often comes to the attention of archaeologists and physical anthropologists and may be of more than passing interest to students of nutrition.

The process may be accentuated by a robust masticatory apparatus and vigorous function or by coarse gritty particles in the food. Even fine silt mixed with the food will cause surprisingly rapid and as much wear as coarse-particle wear in some circumstances (Dahlberg, 1960, 1963). Sometimes attrition is occupational or caused by pipe smoking. In these cases the attrition is more likely to be localized or accentuated locally. Attrition is sometimes associated with chewing narcotics which may be mixed with silicious alkalis. Attrition in prehistoric or primitive peoples becomes generalized in senility but it may be very marked even in childhood. In most races the rate of attrition is slow enough to enable the pulp to protect itself by laying down secondary dentine even though the crowns were worn down to gum level. For some the diet is so coarse that attrition leads to severe pathological destruction of the dentition (Johnson and Snow, 1961).

The fine relationships between tooth wear and occlusal function have been observed by many investigators, notably Begg (1954), Murphy (1964), and Hasund (1965). These researchers have shown that attrition wears away not only the biting surfaces of opposing teeth but also the interproximal surfaces, so that the mesiodistal dimensions of individual teeth are reduced and consequently entire arch lengths, since nature endeavours to keep all the teeth in contact through mesial migration of the dental units. Begg (1954) justifies tooth extractions in orthodontic treatment partly on genetic grounds and partly as compensation for the lack of attrition associated with the modern diet.

It is generally assumed that attrition in former times was associated with a lower incidence of dental caries than is now experienced. Nevertheless the manner of eating and the tooth quality must be taken into account, for Perier (1949) commented that Esquimo attrition is related to the response of heavy function, whereby teeth yield proprioceptively in their sockets and rub against each other to produce wear by friction rather than by an abrasive agent in the diet itself. Even with the soft diet of the modern industrial age dental attrition is occasionally seen, as in cases of bruxism. Masticatory function often succeeds in reducing by facetal wear misplaced cusps interfering with the normal paths of mandibular closure.

Nevertheless functional attrition was frequently caused or accentuated by grit in the diet of former times and at the present time in the food of contemporary ' primitive ' man. Leigh (1925) found the most severe cases of attrition that he had ever seen in the skulls of prehistoric Kentucky Indians, whose diet included large quantities of shell-fish which is a good vehicle for sand.

One of the most accurate descriptions of attrition and its long-term effects on the dentition was written not by a dental surgeon but by a sheep rancher, Lucas Bridges (1948), who eloquently described the condition in elderly Indians of Tierra del Fuego, a people whose protein/fat diet also included large amounts of shellfish.

It is sometimes stated that corn grinding with millstones was a source of grit in primitive breads and that this would lead to dental attrition. The dental conditions of modern Bedouin nomadic tribes are therefore of some interest, especially as agriculture had its origins in the Middle East. Clawson (1936) described the favourite food of the Shamnar Bedouin as being cleaned wheat kernels slightly boiled, dried in the sun for a few days, and then lightly crushed between stones. The coarse-ground wheat grains were then exposed to the sun and wind and the sand of the

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desert for another long period before being cooked with soured camels' milk. According to Clawson sand in the Bedouin diet accounted for much dental attrition.

As sand in the diet cannot be considered a pleasant addition, problems arise as to how much

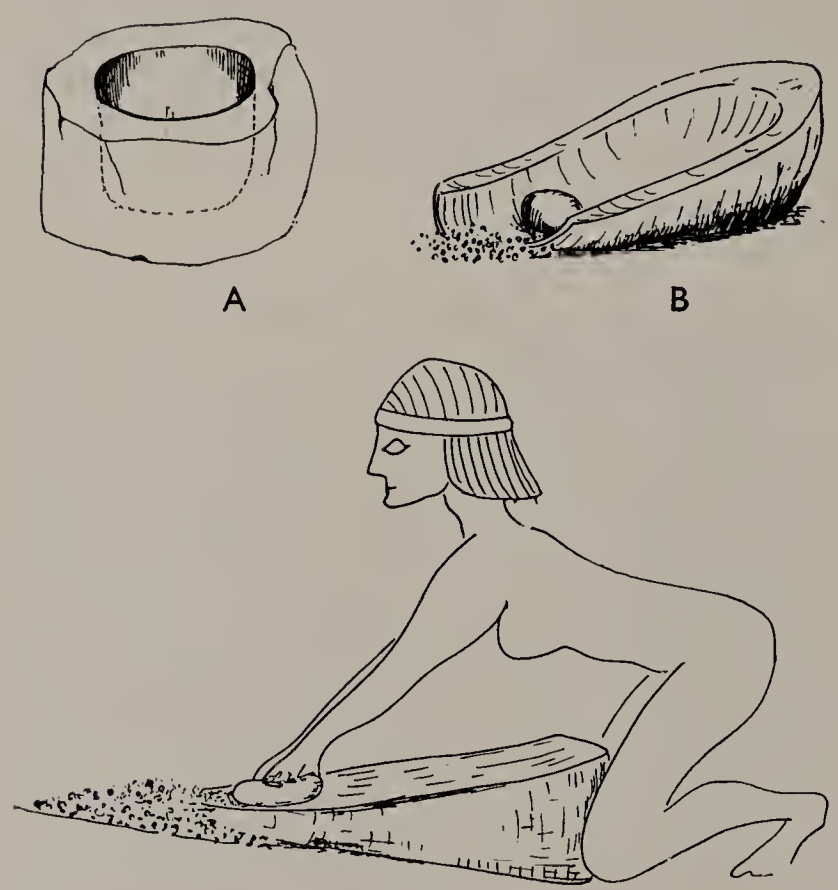


Fig. 1.—A, A Shetland stone mortar ('Knockenstane'). B, A trough quern (Jericho, 7000 B.C.; Jarlshof (Shetland) 2000 B.C.). C, 'The handmaiden that is behind the mill' (Exodus, chapter 11, verse 5).

grit and sand did primitively ground meals and flours actually contain under varying conditions of production and whether they could be removed before consumption as bread or porridge. These problems are best considered by studying the evolution and development of methods of grinding cereal grains with the millstones of bygone days.

THE EVOLUTION AND TECHNOLOGY OF PRIMITIVE CORN MILLS*

Until the advent of roller milling towards the end of the nineteenth century corn milling was essentially a method of grinding cereal grains into meal or flour between two stones of suitable size and shape.

In Stone-age times roots, nuts, acorns, seeds, etc., were pounded into a meal with some kind of pestle of wood or stone in any suitable natural hollow or basin in a convenient rock. The next step was to make a portable 'hollow' of stone or wood—the mortar. Such primitive devices are still used at the present time for preparing food by the cooks of isolated and primitive economies in many parts of the world. In Shetland a stone mortar called a 'Knockenstane' was used to bruise corn to within living memory (*Fig.* 1A).

During Neolithic times revolutionary changes in food production occurred through the advent of cultivated cereal crops in the Middle East. To convert the harvested grain into flour grain-rubbers were developed. The mortar became a wide, shallow, stone basin and the pestle changed into a squat bun-shaped stone easily held in the hand. It could be used to rub the grain round and round or to and fro in any direction within the stone basin.

An alternative development was the saddle quern. This consisted simply of a large wedge-shaped stone with a sloping grinding surface slightly concave both lengthways and from side to side. Sometimes the grinding surface was convex from side to side, but the slope of the working surface was usually upwards about 20–25° from the horizontal. The operator of a saddle quern knelt behind the large stone and converted the grain into meal by rubbing it with a bolster-shaped smaller stone or 'rider' held from side to side across the mill and rubbed in a reciprocating action up and down the sloping grinding surface. No doubt the greatest pressure would be applied during the downwards stroke. The meal and broken grains would collect at the bottom of the slope and would need to be repeatedly ground to produce a fine meal. An examination of such simple mills reveals that the surface of the riding stones by repeated use wear down to fit exactly into the curvatures of the grinding surfaces of the main stones.

Saddle querns became more sophisticated in as much as the peripheries of the side-to-side concavity became built up into side walls. The quern thus became trough-like, open-ended but with the grinding surface sloping downwards exactly as before. This refinement no doubt permitted better control and less spillage of the grain and meal during the rubbing process (*Fig.* 1B).

The Old Testament records history at the time of Neolithic farming and refers to corn milling on several occasions. When it does so it refers only to saddle querns since rotary mills had not yet been invented. Saddle querns of the trough-like kind were in use in Jericho 7000 years ago (Cole, 1959). As Neolithic farming methods spread into Mediterranean countries and onwards into Northern Europe so did the saddle quern. Five thousand years later they were in use at Jarlshof in Shetland, their form

*The word 'corn' in this paper is used in the English sense to mean all kinds of grain, as distinct from the more specific American usage meaning maize or the Scottish signifying oats.

being exactly the same as their precursors in far-off Jericho. Even the manner of operating the mill is described in the Bible, for a sad fate awaited the Egyptian 'handmaiden that is *behind* the mill' in Exodus, chapter 11, verse 5 (*Fig.* 1C).

the grinding surfaces of the mill. Sometimes the periphery of the upper stone was extended upwards to form a hopper for the grain to feed down between the grinding surfaces of the upper and lower cones. Into the sides of the top stone, sockets were chiselled to take long levers for

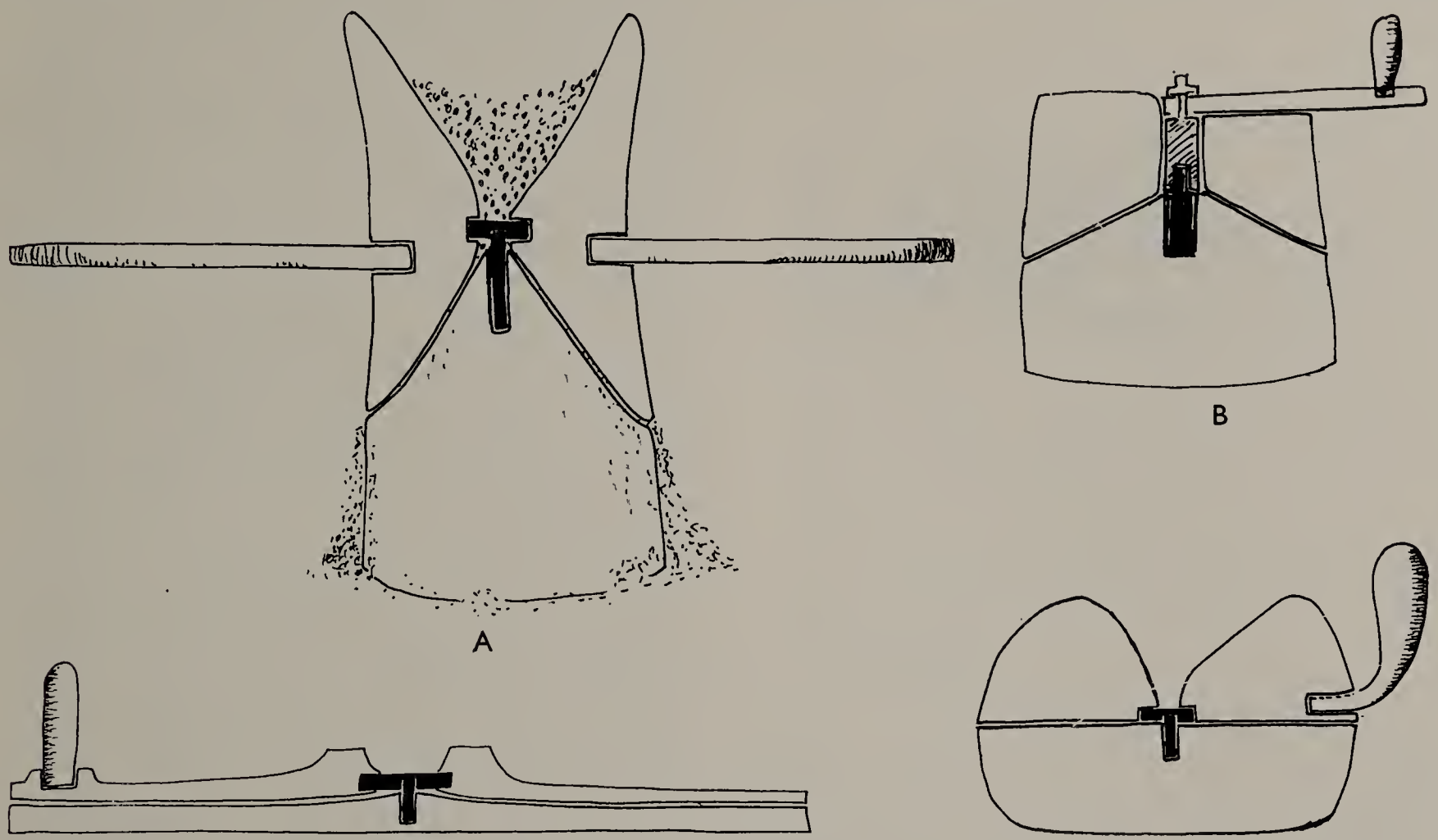


Fig. 2.—A, A Roman slave-mill. B, Early quern from Sussex, first century B.C. (Curwen). C, A Roman beehive quern. D, A Scottish eighteenth-century quern.

The Rotary Domestic Quern

The saddle quern was used for thousands of years and is still used in some countries. One day, somewhere, an inventive genius, no one knows whom, conceived the idea of using a rotary motion rather than a reciprocating action for grinding corn. Thus, the rotary domestic quern was born, which was to oust the older saddle type because of its greater efficiency.

The domestic quern may have been inspired by the Roman donkey or slave-mill, which was a large affair driven by animal or human muscle power. In turn this may have been copied from Greek origins (Curwen, 1937). Equally it might be considered that the large mill was modelled on the small hand quern.

A slave-mill consisted of a large bottom stone with a conical apex into which an iron spindle was inserted in a socket (*Fig.* 2A). The upper stone was an inverted hollow cone which fitted over the lower stone but with its weight carried by an iron bridge, the mill rynd, jammed across the opening into the upper stone and resting on the spindle of the lower. The surfaces of the upper and lower cones sloped 35–40° and formed donkeys or slaves to turn the mill. As the stone turned the grains were ground and appeared as meal and broken grains at the circumference of the mill.

The hand quern consisted of the same five basic parts as the slave mill, namely: an upper stone, a lower stone, a spindle, a mill rynd, and a handle to rotate the upper stone on the lower. The first rotary domestic querns had some other features in common with the slave mill, especially the conical form of the bottom stone and the corresponding concave under surface of the upper stone. They were quite small, being from 12 in. (30 cm.) to 18 in. (45 cm.) in diameter, sometimes even less, but the top stone of these early hand mills was thick and tall enough to accommodate the conical shape of the lower stone (*Fig.* 2B). The upper stone was perforated from the top to the under surface for two reasons. First, the hole fed the grain to the grinding surfaces, and secondly, the lower part of the hole, which was narrower at the bottom than at the top, carried the mill rynd, which was jammed across the hole from side to side but was not wide enough to inhibit the free passage of grain.

The spindle was inserted into a socket in the centre of the lower stone. Its purpose was to carry the weight of the upper stone via the mill rynd. The stones were thus separated by a small free-way space so that only part of the circumference of the upper surface actually touched

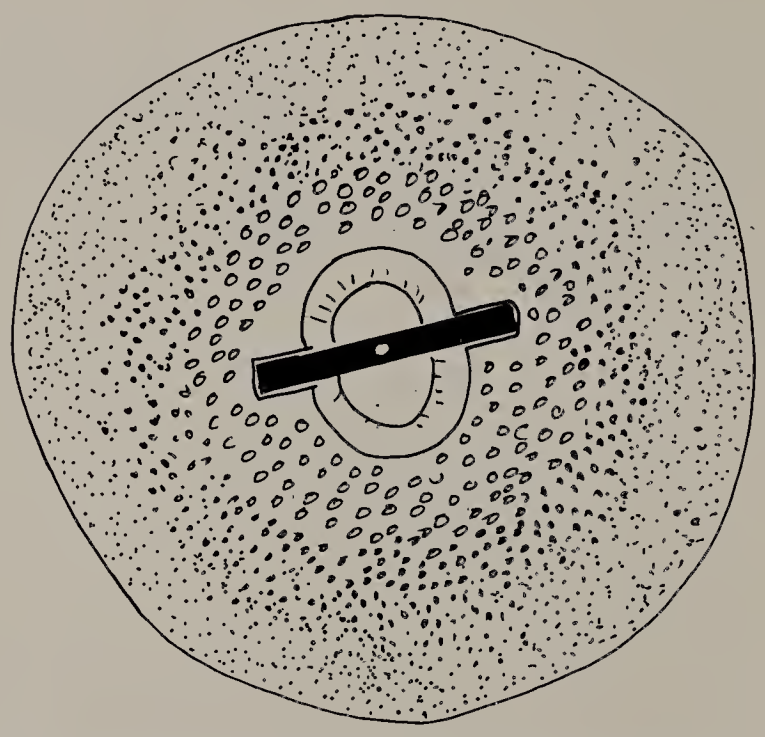


Fig. 3.—Grinding surface of a quern top stone ' picked ' to sharpen the stone (Shetland).

the lower one during the grinding process initially, and then not at all as grain spread by centrifugal forces between the stones. To turn the upper stone on the lower stone either a groove was cut on the top surface of the upper stone in those kinds where this surface was flat or a hole was drilled into the side of the upper stone. Wooden handles were inserted into the groove or hole to drive the mill. Early querns used wooden spindles and rynds but iron was a big improvement.

As the querns evolved they became more efficient. The early kinds allowed too rapid a passage of grain down the sloping surfaces. The slope of the grinding surfaces was gradually reduced and then the top stone was made thinner and thinner. As the stones became thinner their diameters increased, for the most efficient grinding was obtained by centrifugal forces, and the greater the distance the grain travelled from the centre and was subjected to these forces the finer the meal was or the greater the proportion of grain broken down to flour.

The ultimate in evolution was the type of quern used to within recent times in Northwest Europe, Scandinavia, Shetland, Orkney, and the highlands and islands of Scotland. Querns from these regions had flat or almost flat grinding surfaces, sloping upwards a mere 3 or 4°, but with a diameter up to 2 ft. (60 cm.) or even more.

The earlier querns of Roman Britain had almost flat surfaces, but the top stone was still thick and its hemispherical shape caused these mills to be called ' beehive querns ' (*Fig.* 2C). Every tenth man in the Roman legions was responsible for grinding corn in such a quern. The Iron-age querns of the Hebrides were larger in diameter and were essentially two flat discs of stone with wooden upright handle inserted in a socket near the outer edge of the upper stone (*Fig.* 2D).

The kind of stone used to make querns mostly depended on the local rock formations. The top stone of a rotary quern found in North Wales was made from a pale grey dolerite (Dancer, 1970). In Roman Cumberland beehive querns were sculptured from a crisp hard Penrith sandstone, whilst in the north of Scotland granites and mica-schist were utilized in recent times. Sometimes the conglomerate pudding stones were used and these would give excellent grinding surfaces through differential wear. Curwen (1937) describes pot-shaped querns made of larva imported into Britain in Saxon times and during the Middle Ages. Wells (1964) states that this kind of quern produced flours containing 3 per cent grit.

It is conceivable that mill-stone particles would, depending on the variety of stone, contribute minerals of some nutritional value, for instance, fluorides.

The fineness of the meal and its proportion to broken or unground grains exuding from between the millstones, and the amount of grit, if any, depended on several variables:—

1. The weight of the top stone—this became of minor importance.
2. The pressure applied by the operator (no great weight or pressure was required).
3. The speed of turning.
4. The rate of feeding in the grain and especially the amount.
5. The diameters of the grinding surfaces.
6. The kind of rock used to make the quern and hence the degree of grittiness to tear open the grains.
7. The use of grooved or unground grinding surfaces. During quern evolution a stage was reached when improved action was obtained by cutting grooves in the grinding surfaces. Such grooving had to be carefully done and made such querns very expensive. In Shetland stones were picked with finer and finer holes from the edge of the mill towards the periphery—a cheaper but just as effective method (*Fig.* 3).
8. The distance set between the stones via the spindle and mill rynd.
9. The kind of grain used and whether raw or first dried in a kiln or poached in an oven. Barley was the hardest grain to grind to a meal in a quern, wheat and rye being easier than either oats or barley (Curwen, 1941).
10. The number of times the corn needed to be ground or reground to produced meal.
11. The skill of the operator.

Most of these variables could be controlled by the operator, but as the free-way space between the stones was a very important factor in determining the fineness of the meal the ultimate improvement was to perforate the bottom stone as well as the top (*Fig.* 4). The spindle then passed downwards through and accurately fitting the bottom hole to rest on a simple lever, which would be raised or lowered according to the desired space between the stones. The smaller the space the finer the flour was, and, conversely, the greater the space the coarser the meal obtained. If the space was reduced too much then the stones would touch over too great an area and excessive grit would result in the flour.

Parching the corn in an oven hardened it and made it easier to grind in a quern. This was necessary even for the water mills of North Wales in the middle of the nineteenth century (Evans, 1948). To remove the husk from oats the upper stone was raised a little to allow the grain to pass between the upper and nether stones uncrushed. Because the grain had been hardened during heat treatment the hull or husk came away in two pieces. After that the husks were separated from the shelled oats with either a riddle or a small winnowing fan. Thereafter the upper millstone was lowered again and the shelled oats reground into oatmeal. Despite this some husks would still be present in the meal, and would have to be removed by further use of the sieve.

Shelled oats were often used to make ' cuwd rhynion ', this being considered a better porridge than that made from oatmeal. In Scotland the products of the first grind of oats were fermented for making ' sowans '.

Ancient methods of corn milling are often blamed for the production of too much grit in primitive flours. This no doubt often occurred and resulted in considerable dental attrition. Saddle querns very likely were responsible for the production of much grit, but even in the hey-day of the saddle quern grit could always be at least partly removed by sifting or bolting through cloth, the residues being used for animal feed.

When Joseph was cast into prison by Pharaoh the Jewish Talmud says he found the butler and the baker in the same cell. The baker's crime was to displease Pharaoh by allowing too much grit in the flour used for a state banquet.

With the rotary quern, grit was still a problem, but less than might be supposed. As long as grain was always being replaced between the stones, grit production would be minimal. If too little grain reached the interfaces the grinding surfaces came into contact with each other much more, resulting in a greater production of grit. Much depended on the skill and practice of the operator.

For fine flour the quern production required to be reground several times and then bolted through cloth. As this increased the amount of labour needed only rich households with many servants could afford a whiter loaf of bread. Nevertheless in primitive flours some of the grain husk would remain, and as the husk of barley and oats is particularly rich in silica this alone would account for some attrition. Oat husks are also suspected of containing an anti-caries agent. Over two-thirds of the ash content of oat husk consists of silica, and oat husk as a by-product of modern milling is used as an abrasive in the air-blasting of machined metal components (Kent, 1966). In Norse Greenland querns were used for many purposes such as grinding roots of the willow herb (*Epilobium augustifolium*), moss, or fish bones (Ingstad, 1966). Querns were used during a long period of human history. In Cumberland they were used up to the early part of the nineteenth century (Bennett and Elton, 1898) and they were also used as late as this in North Wales (Evans, 1948). On the Scottish islands they were in use well into the present century, and quern-ground flour was sifted through a sieve made from a perforated sheepskin.

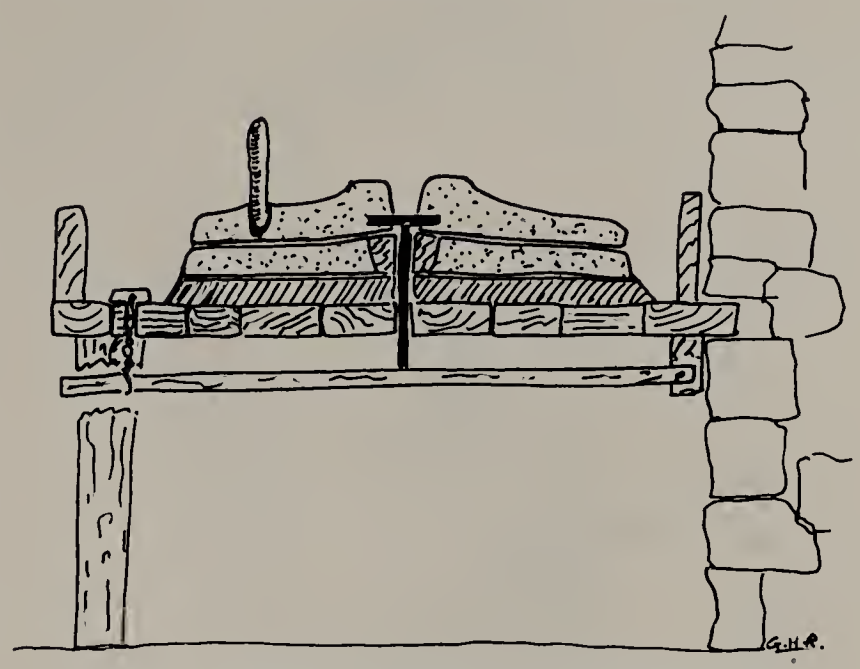


Fig. 4.—Final development of the quern stone showing how the upper stone could be raised or lowered by a lever (Unst, Shetland).

The quern is a miniature mill driven directly by human hands. In Britain larger mills were developed in the Middle Ages, and human muscles were taken over by wind and water power turning much larger stones. No matter how large the stones became the essential working parts of the mill remained the same five basic components of the hand-mill with the handle becoming a driving shaft.

In some places in Britain flour is still being ground with large stones driven by water wheels with a horizontal shaft. Until the end of the past century small stone-built mills were in

common use in Shetland. They were numerous not only in Shetland but also in Norway, Sweden (Mankar, 1965) and the Faroes (Williamson, 1948). They are described as ' Norse mills ' but their origin was in the Middle East. In Shetland their ruins can often be seen alongside surprisingly small streams. They had vertical shafts with paddles forming a turbine called the ' Tirl ' to turn the top stone via an adjustable spindle passing through the perforated lower stone (*Fig.* 5). Such a mill was described by one of Sir Walter Scott's (1896) characters in *The Pirate* as a ' miserable molendinary . . . a bairns wirlygig . . . just one degree better than a hand-quern ' not able to ' grind a bickerfu ' of meal in a quarter of an hour and that more ' . . . like a mash for horse than a meltitth for man's use '. Suffice it to say that this disparagement was amply and sturdily contradicted!



Fig. 5.—A Shetland mill.

EXPERIMENTS WITH QUERNS

In order to find out how much grit, if any, became incorporated in quern-ground flours and under what circumstances a series of experiments and flour analyses were carried out.

Three quern stones were used:—

1. A home-made replica of a Roman beehive quern. This was sculptured from Lazonby sandstone, a rich red-brown but fine grained and fairly soft sandstone. This stone was really too soft for milling purposes. Also it was smaller than ancient beehive querns, the diameters of which were at least 15 in. (37·5 cm.) and more likely 18 in. (45 cm.) (*Fig.* 2C).

2. A Shetland pair of quern stones from the Island of Unst. These stones were not an original pair but the top stone filled the lower accurately enough to grind corn. Both top and bottom stones were made from a granitic gneiss.



Fig. 6.—The author using the Shetland quern illustrated diagrammatically in *Fig.* 2.

Table I.—Diameters and Weights of the Top Stones of Three Different Querns

Type of Quern	Diameter of Top Stone	Weight of Top Stone
Aberdeenshire	20 in. (51 cm.)	93 lb. (42 kg.)
Roman Beehive	12 in. (30 cm.)	31 lb. (14 kg.)
Shetland	21 in. (53 cm.)	48 lb. (22 kg.)

3. An original pair of quern stones from the upper reaches of the Don Valley, Aberdeenshire. Both stones were made from unpolished pink granite.

The bottom stones of both the Shetland and Aberdeenshire querns were perforated for an adjustable spindle. The dimensions and weights of the top stones of the three querns are shown in *Table I.*

Four different kinds of grain were ground to flour in each of the three querns: oats, barley, bere (from Shetland), and wheat. All had been dried in modern grain driers except the Shetland bere.

It was found for all three querns that wheat was the easiest cereal to mill. Being a naked grain the 100 per cent extraction flour could be used to make bread, although in actual fact for

experimental purposes the flour was separated from the bran by means of a modern housewife's sieve.

Bere was almost as easy to grind as wheat but, like oats and barley, it has a husk or hull and requires sieving to separate the meal. Bere is a primitive barley. It was grown extensively in various places in prehistoric times and still is in Shetland and Orkney. Bere-meal for making a delectable porridge can still be bought in Aberdeen, and Kirkwall shops sell bere-meal bannocks. It is a loosely constructed grain with an awn which persists after harvesting.

Modern barley is a very hard compact grain and was the most difficult of the four cereals to mill in all three querns. Curwen (1937, 1941) also found barley the hardest grain to grind to a meal. For these experiments the variety Ymer was used.

Oats were found to be easy to grind but the meal was more difficult to separate from the large amounts of hulls with the means available (sieving).

Each kind of grain was ground to an acceptable flour, and the number of times a grain needed to be ground and reground depended on the kind of cereal and the quern. The grain needed from one to four times with the Shetland and Aberdeenshire querns; up to six times was necessary for wheat, while Ymer barley with the replica Roman quern required several more times.

The Shetland quern (*Fig.* 6) ground even Ymer barley far more efficiently than the ' Roman ' mill, but much depended on the weight of the barley actually ground. The ' eye of the mill,' i.e., the central hopper in the top stone, could hold 1 lb. (454 g.) of Ymer barley, but to convert this amount of grain to a meal it had to be ground and reground eleven times and required 40 minutes to produce 14 oz. (396 g.) of unsieved meal. After sieving, 6 oz. (170 g.) of fine meal and 5 oz. (142 g.) of very coarse meal made up the final product together with the residues and $1\frac{1}{2}$ oz. (42 g.) was lost.

When too much barley is put into the mill each grain acts like a ball bearing and thus with a large amount of barley less weight is imposed on the individual grains and hence there is a greater resistance to disintegration of the grains. By reducing the amount of barley to 8 oz. (227 g.), meal was produced in 15 minutes.

One pound (454 g.) of wheat required five grindings in the Shetland quern to produce $15\frac{1}{4}$ oz. (432 g.) of fine meal, but 8 oz. (227 g.) only needed four grindings in 11 minutes. The Aberdeenshire quern required still fewer grindings for comparable amounts of all the cereals used.

Analysis for Grit

Samples of each kind of grain were analysed at each stage of production in order to determine the grit content of the meals and flours produced by the three querns.

Each sample was ashed in duplicate for 16 hours at 480° C. The ash was then extracted with hot nitric acid and dried to provide a measure of acid-insoluble ash, which was largely silica. Any possible acid-soluble content of quern-derived grit was regarded as negligible.

Table II shows the grit content in samples of successive millings of wheat in the Shetland quern.

Table II.—Percentage of Insoluble Ash in Samples of Undried Wheat Flour ground in a Shetland Quern

Milling	*Insoluble Ash* (per cent)
First	0·02
Second	0·03
Third	0·12
Fourth	0·16
Fifth	0·18
Sixth	0·17
Sixth (sieved)	0·17

Table III.—Percentage of Insoluble Ash in Samples of Undried Meals ground in an Aberdeenshire Quern

Milling	Insoluble Ash (per cent)			
	Oats	Wheat	Barley (Bere)	Barley (Ymer)
Whole grain	0·81	0·13	0·80	0·33
First	0·94	0·05	0·72	0·35
Second	—	0·12	0·90	0·26
Third	—	0·10	—	0·34
Fourth	—	—	—	0·38
Sieved	1·02	0·23	0·64	0·82

There is a general tendency for the grit content to increase with successive millings. Inconsistencies arise through difficulties of sampling and because fine quern-derived grit probably passes through the sieve leaving husk-derived ash with the residues. Nevertheless the grit/ash content remains small.

Biscuits made from wheatmeal produced in the Roman quern and incorporating honey tasted very good except for the very evident grit. Obviously persistence with such a diet, vigorously chewed, would produce marked dental attrition.

Biscuits and bread made from wheaten flour milled in the efficient Shetland quern did not give the slightest sensation of grittiness. Even after six millings, which is far more than is necessary, the grit content in the flour remained astonishingly small although it increased after each successive grinding (*Table II*).

Table III shows the grit content in successive grindings of barley (Ymer), bere, wheat, and

oats in the Aberdeenshire quern. The number of millings needed to produce an acceptable meal varied according to the grain.

For the Roman quern roasted whole barley (Ymer) grains were used. An unground sample yielded 0·45 per cent of insoluble ash. After one grinding this had increased to 1·8 per cent, but very little of the barley was successfully milled at this stage. Six millings were needed to produce an acceptable meal and a sample of the sixth milling yielded no less than 17·1 per cent of insoluble ash, representing the visibly obvious quern-derived grit.

From these analyses it can be seen that the corn mills of bygone days did produce some grit in the daily bread of the people, but that it was not very significant when the mills and the milling were efficient. Inevitably the amount of grit would produce some dental attrition, but to varying degrees. Moreover the millstones themselves were also subject to attrition. The fact that they required periodic regrooving, or in Shetland repicking, to ' sharpen ' the grinding surfaces in itself indicates loss of stone into the meals and flours. The stones of Shetland water-mills when in continuous use had to be repicked every 2 or 3 weeks (Goudie, 1904). Quite apart from regrooving and repicking quern stones would gradually wear thinner and thinner over a number of years.

The Life of a Quern

If 0·1 per cent grit production is agreed for a Shetland-type quern then 2000 lb. (900 kg.) of grain reduced to meal would cause a loss of 2 lb. (908 g.) of grit from the upper and lower millstones, i.e., 1 lb. (454 g.) per stone. Assuming that one individual consumes the products of 2 lb. (908 g.) of grain per day, then approximately 700 lb. (315 kg.) of grain would be required by one person in 1 year or about 1 ton (1008 kg.) in 3 years.

Therefore if a top stone weighing 48 lb. (21·6 kg.) loses 1 lb. (454 g.) of its weight in 3 years the quern would last 96 years, assuming that it remained efficient until two-thirds of its thickness were worn away. By picking the stone to 'sharpen' it this period would be further reduced.

Microscopic Examination of Meals and Flours with Polarized Light

In addition to the chemical analysis wheat and barley flour from the Shetland and Roman querns respectively was examined microscopically under polarized light.

Under such conditions starch granules show as small fairly regular dots on the microscope slide, silica particles (grit) appear as irregular masses, and fragments of barley husks as elongated shapes.

The wheat flour from the Shetland quern appeared as a homogenous collection of starch granules with practically no indication of grit, but the barley meal from the Roman quern showed as a chaotic mixture of starch granules, husk fragments, and grit particles.

CONCLUSIONS

The experiments carried out with reinstated querns serve to illustrate that grit was not an unavoidable ingredient in the diet of prehistoric or more recent agriculturists. Milling efficiency combined with effective winnowing, holting, and sieving could reduce the grit content of primitive meal, flour, and bread to negligible proportions.

Wide variations in degrees of dental attrition in skulls of comparable age from a particular historical period could be related to the kind of stone used to manufacture corn mills, the design of the mills, the efficiency of the miller, and whether the skulls belonged to rich householders or poor ones.

Rich householders, being able to afford the best millstones, could also employ many servants to produce fine meal. They could afford the greater wastage entailed through successive winnowings and sievings and by repeated millings which would increase grit content. In this manner they would tend to experience less dental attrition than their poorer brethren provided that other items such as raw shellfish were not a major constituent in the diet.

Acknowledgements

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I am also indebted to my wife and many friends in north-east Scotland and Shetland for their interest, and especially to Mr. John Allan, Chief Dental Officer, Shetland, and Squadron Leader H. Haines, R.A.F. Saxavord, Unst. Mr. E. A. Tait, Reader in Geology and Mineralogy, University of Aberdeen, kindly undertook the geological assessment of the quern stones. I should like to thank Miss P. Scott, for undertaking the task of typing this contribution.

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ANTERIOR RETENTION IN THE REMOVABLE APPLIANCE

J. D. MUIR,* B.D.S., F.D.S., D.Orth. R.C.S.

Consultant Orthodontist, City General Hospital, Stoke-on-Trent

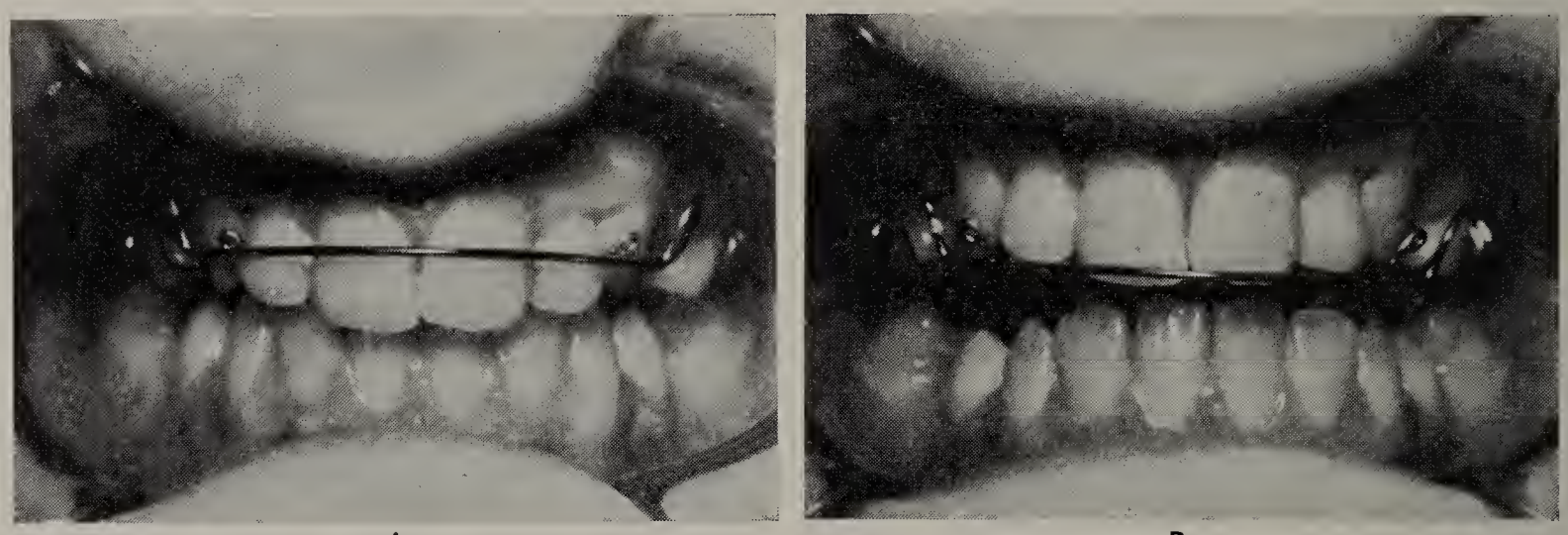
INTRODUCTION

'WILL I have to wear a brace?' This question must be one of those most regularly asked by the young patient at the first visit to the orthodontist.

A 'brace' is the term used almost universally by the layman to describe an orthodontic appliance and is usually a removable appliance possessing almost inevitably a wire across the anterior teeth. Indeed for many patients not actually undergoing treatment the acrylic palate and springs are unknown; only the labial bow is instantly recognized.

Why do so many removable appliances, especially in the south of England, include a labial bow? Is it to improve function, for economy, or merely for the sake of convention? At any rate one of the most popular appliance designs includes as its two commonest features: universal clasps on the upper first molars, and a long labial bow with plain or reverse loops. In itself this can be a very suitable design for a retainer. The molar clasps provide adequate retention and the bow splints the anterior teeth against the acrylic palate. During active treatment, however, the springs often produce displacing forces which the labial bow may be ill-suited to combat (*Fig.* 1).

An economic attraction may be that after the retraction of the upper canines in a Class II, division 1 case the incisors may be moved back on the same appliance either by the activation of the labial bow itself or by an auxiliary self-straightening wire wound on to the bow. Where only a slight overjet exists this may be quite feasible, but in many cases it is far from ideal.



A B

Fig. 1.—The conventional labial bow: (A) with the appliance supported by the lower incisors; (B) with the teeth apart—the activation of the springs displaces the appliance.

The labial bow may also function as a guide when teeth are moved across the labial segment, but it is frequently included on an appliance when it serves neither of these purposes.

ANCHORAGE

The reason for the widespread use of the labial bow is that it has been held by many authorities to assist in maintaining anchorage by preventing proclination of the incisors during retraction of cheek teeth with a removable appliance. White, Gardiner, and Leighton (1968) state: 'A rigid labial bow may be constructed to engage the labial surfaces of the incisors at the junction of

* Formerly at the Royal Victoria Hospital, Bournemouth, where this paper was prepared.

Presented at the Country Meeting held on 24 April, 1971.

the cervical two-thirds and incisal one-third of each crown. Provided it is rigid, this bow will splint the incisors . . . . and interfere with their inclination labially.' They add that a fitted labial bow makes the interference more complete.

Tulley and Campbell (1970) state: 'If the labial bow is set near the incisal edge of the upper incisors, and the plate fits closely to the cingulum . . . . the plate does seem to have a splinting effect on the upper labial segment when teeth in the buccal segment are moved distally.'

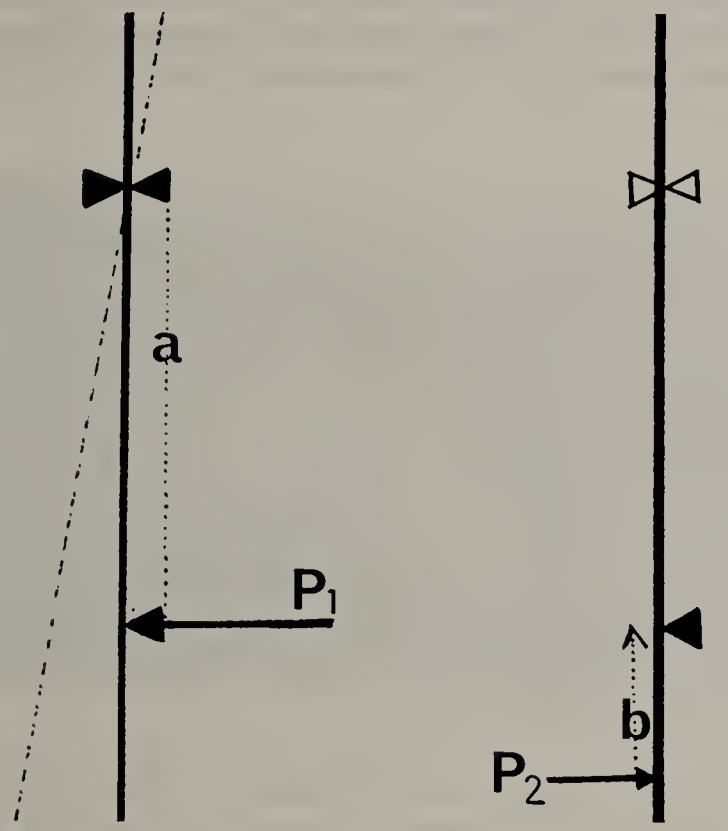


Fig. 2.—A, The effect on an incisor of the force P_1 delivered by the acrylic of a removable appliance if anchorage is lost during retraction of buccal teeth. B, The effect which a force P_2 delivered by a labial bow must have if tipping of the tooth is to be avoided.

Walther (1967) in *Orthodontic Notes* places fourth in a list of ways of reinforcing anchorage, '. . . . labial bow, plus thickening of the plate anteriorly. This has the effect of splinting the incisors.'

It is interesting to note that these statements are in each case much more cautious and qualified than those in the previous editions of the same works. This seems to indicate a growing disenchantment with the labial bow as a method of increasing anchorage.

THE FORCES INVOLVED

A diagrammatic representation of the forces acting upon an incisor as the cheek teeth are retracted (*Fig.* 2A) shows that the force P_1 applied by the acrylic base to the cingulum of an upper incisor sets up a rotating couple P_1a about a point roughly one-third of the root length from the apex which tends to tip the tooth labially. To prevent such tipping a labial bow must be capable of exerting a force P_2 (*Fig.* 2B) on the labial surface of the crown so that an equal and opposing couple P_2b is set up about the point where the acrylic touches the cingulum.

It is difficult to determine accurately the position of the fulcrum for either rotating couple or to estimate how much force is delivered by the acrylic to an individual incisor but it is evident that distance a will be much greater than distance b. If P_2b is to approach P_1a in magnitude this discrepancy must be minimized by moving P_1 as far apically and P_2 as far incisally as possible. The force P_2 must also be as great as possible.

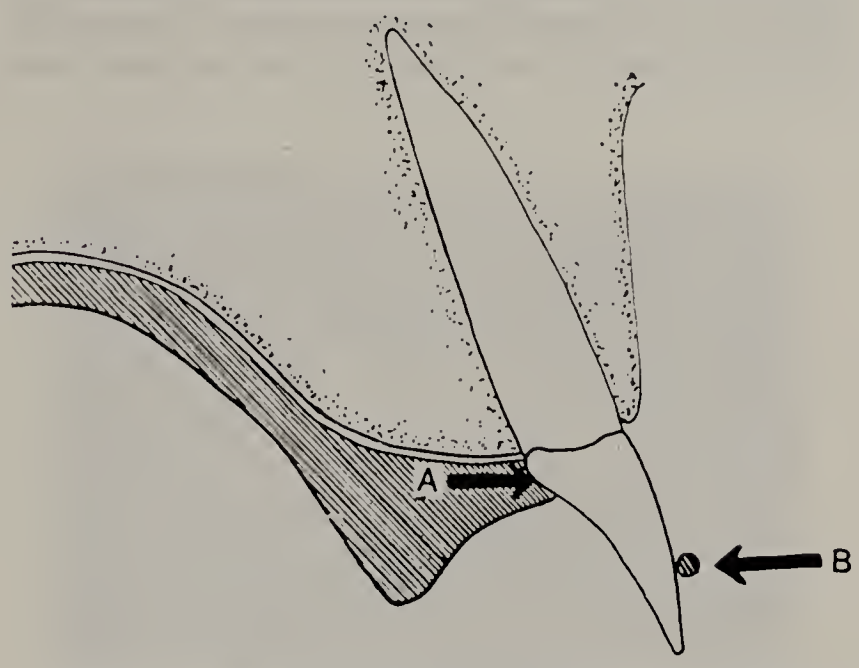


Fig. 3.—The traditional textbook picture, showing the labial bow (B) well below the level of the acrylic base-plate (A).

The extent to which P_2 may be positioned incisally is limited by the height of the bow relative to the shortest of the anterior teeth (usually the lateral incisor) and the ease with which the bow may be displaced incisally during wear. Usually it can be placed securely no nearer the incisal edge than one-third of the central crown height.

The position of P_1 is limited by the palatal gingivae. The diagrams from each of the three works quoted earlier (Walther, 1967; White and others, 1968; Tulley and Campbell, 1970) seem to be based on a gingivectomized patient (*Fig.* 3). A more realistic picture (*Fig.* 4) was provided by taking impressions of children with and without appliances in place and superimposing tracings of the sagittally split models. The relationship of the labial bow to the palatal acrylic was then seen to be very different, in the average case, from the traditional textbook picture, with little vertical discrepancy between the heights of the labial wire and the palatal acrylic.

An experiment was carried out to test the stability of the long labial bow and the short labial wire fitted only around the incisors, using the method and device described by Bass and Robinson (1969) in their paper on the forces involved in incisor retraction. By means of a

swinging arm this apparatus (*Fig.* 5) magnifies the movement occurring at the centre of a labial wire when a load is applied.

Each appliance was tested to find the stability of the wire in the horizontal and vertical planes. Obviously the long labial bow was the more flexible, but in the horizontal plane it was surprisingly firm and a pressure of 50 g. only moved it forward by 0·5 mm. In the vertical plane, however, 50 g. pressure deflected the wire upwards by 3·2 mm. and even 30 g. gave 1·9 mm. deflexion. The fitted labial wire around the incisors was much more rigid; 50 g. pressure produced horizontally only 0·15 mm. deflexion and vertically 0·6 mm., and even a force of 200 g. horizontally produced only 0·5 mm. of movement.

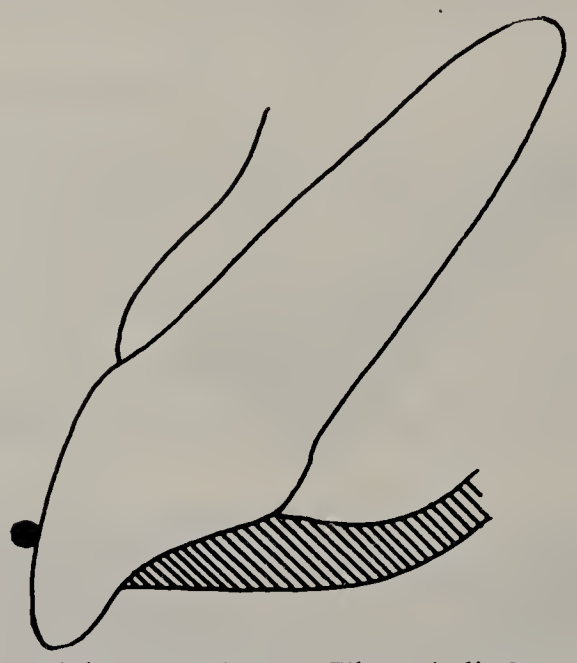


Fig. 4.—The true picture. There is little vertical separation between the wire and the acrylic.

The conclusion is that if the bow is to be effective in reinforcing anchorage it must be rigid and correctly positioned on the teeth relative to the palatal acrylic. The long labial bow is too flexible to be of much value. The shorter fitted labial wire on the upper incisors is rigid enough to withstand a heavy pressure and remain at the correct height, but it must be noted that, particularly in younger patients, the height of the palatal gingiva often makes it impossible to obtain the desired vertical separation between the levels of the acrylic base-plate and labial wire. In addition it should be remembered that if anchorage slip occurs the appliance may slide slightly forwards up the sloping palatal surfaces of the proclined incisors. A fitted labial wire which is already near the incisal edges does little to prevent this as it cannot engage much undercut.

RETENTION

An important consideration in the design of a removable appliance is the provision of good retention.

The patterns of clasps used to retain orthodontic appliances have been many and varied, but the universal or modified arrowhead clasp described by Adams (1970) is probably the most successful and its advent has revolutionized removable appliance treatment in this country.

The clasp is too well described by Adams and too well known to require description here. It will suffice to point out that it should not engage undercuts too deeply. Seel (1966) states: ' the use of undercuts of about 0·01 mm. gives an adequate and optimal crib. ' It should also not be active to any great degree when in position. The clasp is most commonly used in upper first molars but may be adapted for almost any tooth.

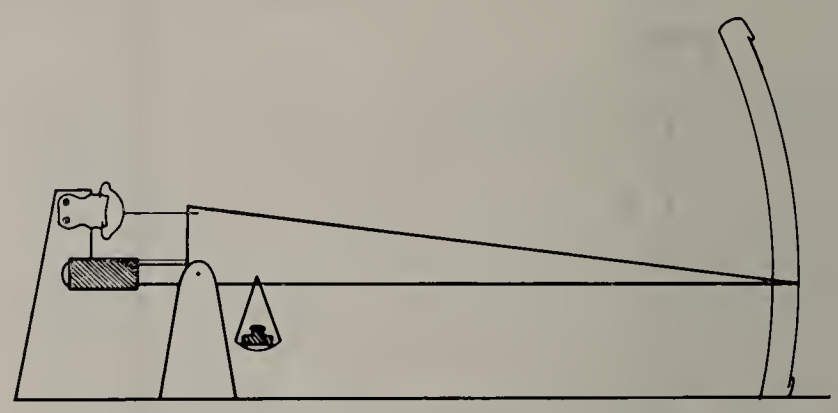


Fig. 5.—The apparatus used to measure deflexion of the labial bow. The appliance is bolted in position and the deflexion compared under varying loads.

DISPLACING FORCES

It has already been mentioned that a long labial bow with clasps on $\underline{6|6}$ forms an excellent design for a removable retainer, but except when the incisors are proclined severely the bow does little to combat any displacing forces to which an active appliance may be subject. Such forces may be set up in several ways:—

1. Spring Activation

a. The most obvious example of a displacing force may be seen when an attempt is made to procline an instanding incisor over the bite. The palatal spring pushing against the sloping palatal surface of the incisor will produce a downward force on the anterior part of the appliance.

b. During retraction of the canines with palatal springs any gingival activation of the spring to separate the canine from the lateral incisor will produce a downward force on the anterior part of the plate. Similarly, on a conical canine ordinary distal activation of the spring may cause it to slide occlusally up the mesial slope of the cusp, again tending to cause displacement.

2. Habits

Often a child may adopt the habit of moving the appliance repeatedly up and down with the

tongue. This can be a major cause of clasp and spring breakage and such habits will occur more readily if there is not sufficient retention anteriorly on the appliance.

3. Extra-oral Traction

If extra-oral traction is applied directly to a removable appliance it can cause displacement, especially when a cervical strap is used. When this is attached via a Kloehn bow to tubes on molar cribs it flexes the clasps, pressing the front of the appliance down. Where facilities for banding are available this problem may be overcome completely by applying the extra-oral traction direct to molar bands and clipping the removable appliance to the bands. If this is not possible, the use of a full headgear will reduce the downward flexion, but in any case the appliance will be less likely to displace if there is good retention anteriorly.

In each of these cases a displacing force is produced. The molar clasps offer good resistance to this and it is usually the anterior part of the appliance which is first displaced.

Good retention is important for a number of reasons. First, it improves the mechanical efficiency of the appliance by ensuring that the springs are continuously held accurately in position. Secondly, because the appliance is a firm fit the patient adapts to it more readily and habit movements are not encouraged. Thirdly, extra-oral traction can be added without the risk of displacement, and, finally, the anchorage contribution from the fit of the appliance against the palatal mucosa and the other teeth is maximized.

Ideally the design of a removable appliance should provide retention anteriorly, and for maximum efficiency any clasping should be placed as far from the molar clasps as possible. Three- or four-point retention is the ideal. Extra clasps will offer little advantage and may actually impede insertion.

Some operators, particularly in recent years, have favoured the use of a universal clasp anteriorly, usually on the two central incisors. In selected cases this provides ideal retention, but used indiscriminately the clasp may offer slight advantage, make removal and insertion difficult, and be prone to frequent breakage.

How then can retention best be provided anteriorly? A variety of clasps are available, and an unusual problem may require an unusual design, but I most commonly use (*a*) the universal clasp (single or double), (*b*) a fitted wire clasping the central incisors, and (*c*) a fitted wire clasping the central and lateral incisors. The last two may be constructed with or without loops.

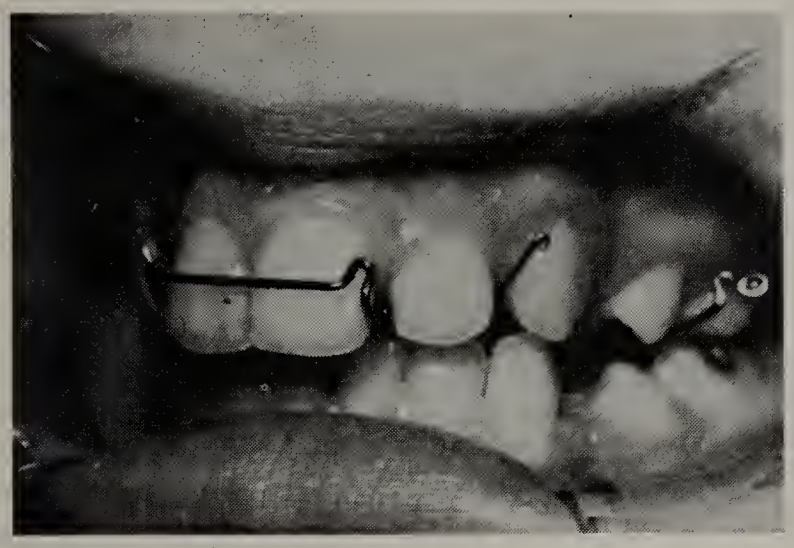


Fig. 6.—The universal clasp applied to $\underline{1|1}$. This provides good retention when the incisors are only mildly proclined.

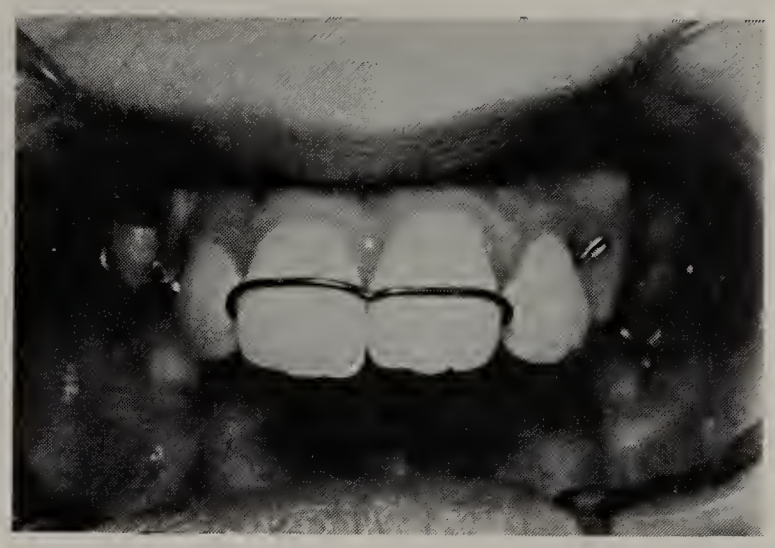


Fig. 7.—The fitted wire around $\underline{1|1}$. This provides excellent retention when the incisors are proclined and leaves $\underline{2|2}$ free to space.

When considering the anterior clasping to be used during retraction of the upper canines or premolars the points to be noticed are the degree of crowding or spacing of the labial segment, and the axial inclination of the incisors. Clasps which hold only the central incisors allow the lateral incisors to drift distally as the canines are retracted. If the lateral incisors are stepped palatally to the centrals this is desirable, but if the incisors already bear a good relationship to each other or are spaced it may be better to use a clasp which controls them.

Clasps holding $\underline{1|1}$ only

a. The Universal Clasp $\underline{1|1}$ (*Fig.* 6)

This may be used when the central incisors are upright, or only mildly proclined. The clasp may be modified slightly by curving the bridge and flattening the arrowheads so that it stands out from the teeth rather less. Dickson and Wheatley (1964) describe such a modification.

On proclined incisors the universal clasp is not satisfactory. There is too much undercut labially, especially if the arrowheads are taken right up to the gum—and if they only engage the correct amount of undercut the bridge will be left perched

on the most prominent part of the teeth near to the incisal edges. The path of withdrawal and insertion of the appliance is important. The usual method involves disengaging the molar clasps before lifting down the front of the appliance. If the arrowheads are already firmly against the labial surfaces of the proclined incisors the clasp will be severely flexed, especially if the patient pulls down the back of the appliance too firmly.



Fig. 8.—The fitted wire around $\underline{1|1}$ with small loops. The loops provide some added retention on incisors which are only slightly proclined. The clasp lies flush against the teeth and is especially useful when there is midline space.

central incisors and themselves offer some retention (*Fig*. 8). This stands out less than the universal clasp and is also the better choice when there is a midline space, as the wire conforms to the shape of the teeth and does not permit any pressure from the arrowheads to cause movement.

Clasps which control the Lateral Incisors

A Fitted Wire on $\underline{21|12}$ (*Fig*. 9)

This may be used when the lateral incisors bear a good relationship to the centrals. It provides a way of keeping them in this position, and also means that the wires pass over the lateral/canine embrasure, instead of the central/lateral embrasure. The morphology of the teeth usually makes this easier, and also means that the clasp is less likely to be damaged by the lower incisors.

The clasp is not kept incisally but lies about half way up the labial face of the incisors where the undercut is improved.

There is a tendency for the lateral incisor to escape from this clasp unless the wire is kept well gingivally where it passes around the distal aspect of this tooth. If the relationship of the canine to the incisor does not permit this, loops should be incorporated into the clasp to provide enough wire for adjustment once this is possible (*Fig*. 10). Where the labial segment is proclined severely

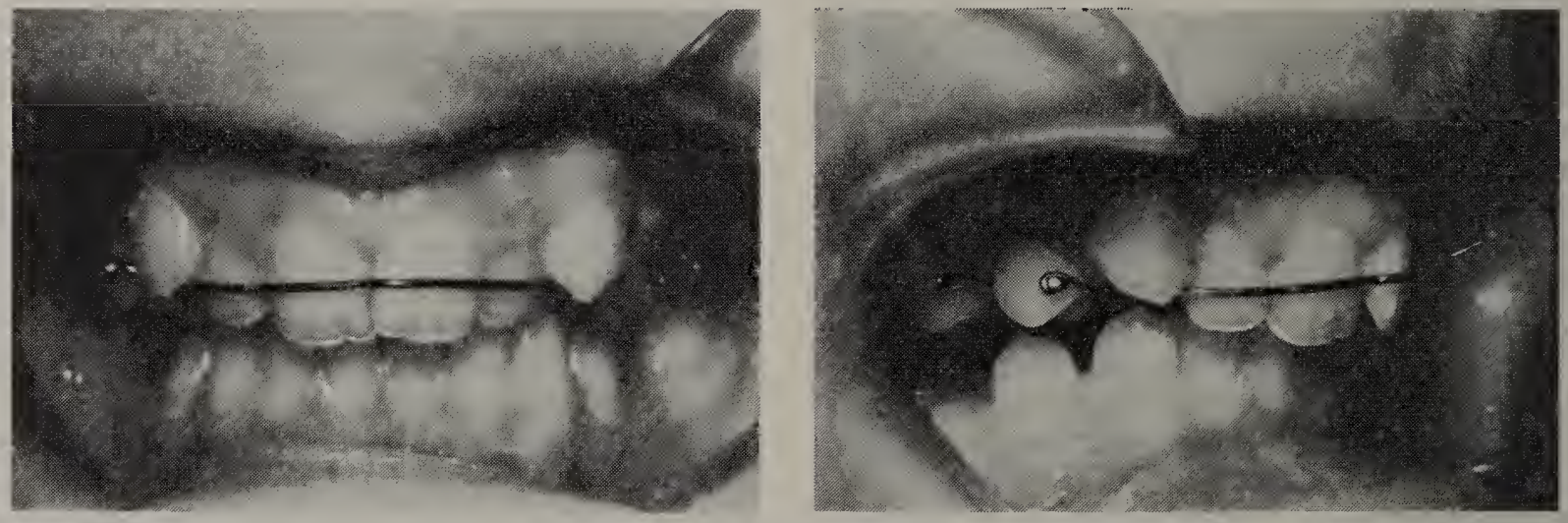


Fig. 9.—The fitted wire around $\underline{21|12}$. The wire passes half way up the central crowns and holds the incisors firmly.

b. Fitted Wire $\underline{1|1}$

On proclined central incisors a fitted labial wire (*Fig*. 7) is preferable. The absence of arrowheads means that the previously described method of removal may be used with very little flexion of the clasp. During insertion the fitted wire is a useful guide for the patient who is new to the appliance. The wire is positioned over the central incisors and the back of the appliance is pushed up into place. This locks the labial wire into position giving excellent retention.

The same design but incorporating small loops is useful if the incisors are more upright. The loops fit flush against the labiodistal corners of the little is gained by contouring the wire around the teeth, and a plain bow across the incisors with small loops by the laterals offers good retention.

Other Designs

Many other retention designs are possible depending upon the particular problem (*Fig*. 11).

Where a central incisor is to be pushed over the bite a universal clasp may be applied to the opposing central or lateral incisor, to the canine or a first premolar, or to a deciduous canine or first molar, in addition to the normal clasps on

6|6. Clasps on deciduous teeth are better made in 0·6 mm. wire.

When tooth movement is being carried out unilaterally a clasp on the first premolar on the opposite side is unobtrusive and gives excellent retention.

If it is desired to leave the anterior teeth unclasped to improve the appearance or because these teeth are to be moved, retention can be improved by placing a single arrowhead in 0·8 mm. wire on the mesiobuccal corner of the upper second premolar. This is superior to the auxiliary clasp normally described. The increased gauge of the wire makes it robust although easy to adjust, and avoiding the soldered joint makes construction easier and lessens the likelihood of breakage.

During retraction of the labial segment the incisors cannot be clasped. If they are proclined the action of the retraction spring will itself help to retain the appliance. In cases where extra-oral traction is to be used, however, or where one wishes to continue with retraction of the incisors whilst keeping the lower teeth gagged on the anterior bite plane, retention can be a problem and it may be useful to clasp 3|3 instead of merely using stops mesial to them (*Fig.* 12).

CONCLUSION

The conventional long labial bow still has a valuable place in treatment: to reduce mild overjets and accept auxiliary springs; to retain the labial segment after tooth movement; to guide teeth being moved across the arch. As a way of reinforcing anchorage it is most uncertain owing to its flexibility. It offers little retention except where the incisors are very proclined and even then a shorter wire around the incisors is probably better.

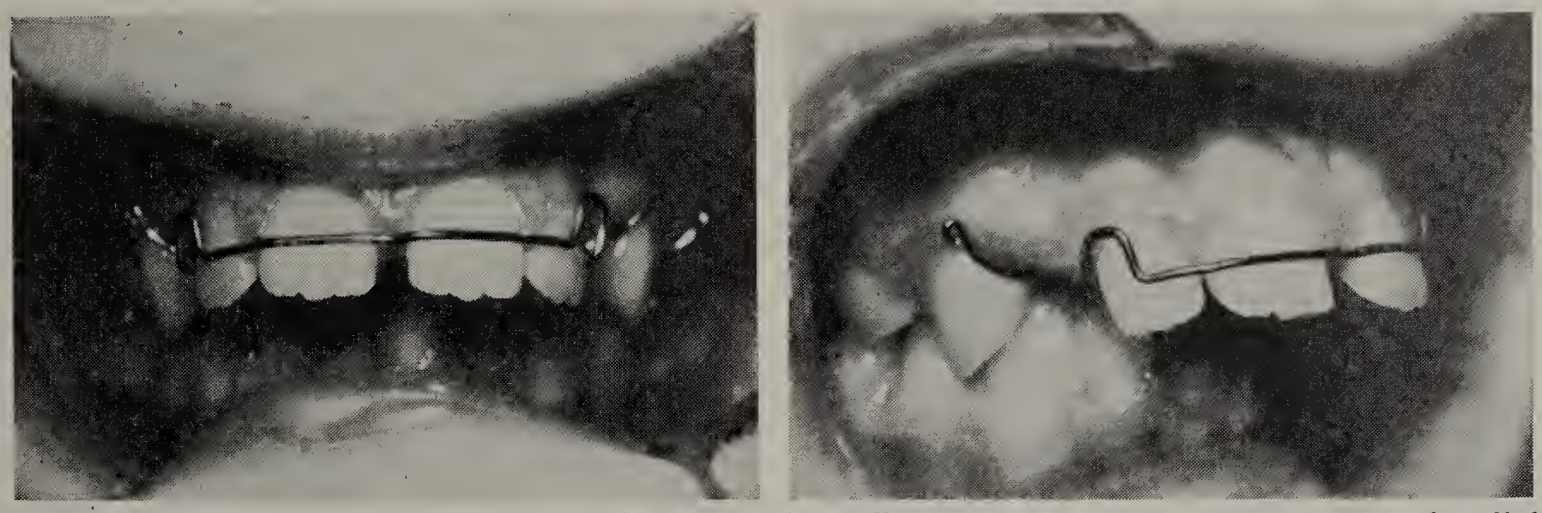


Fig. 10.—The fitted wire around 21|12 with loops. This offers good retention and prevents the slightly spaced incisors from spreading further.

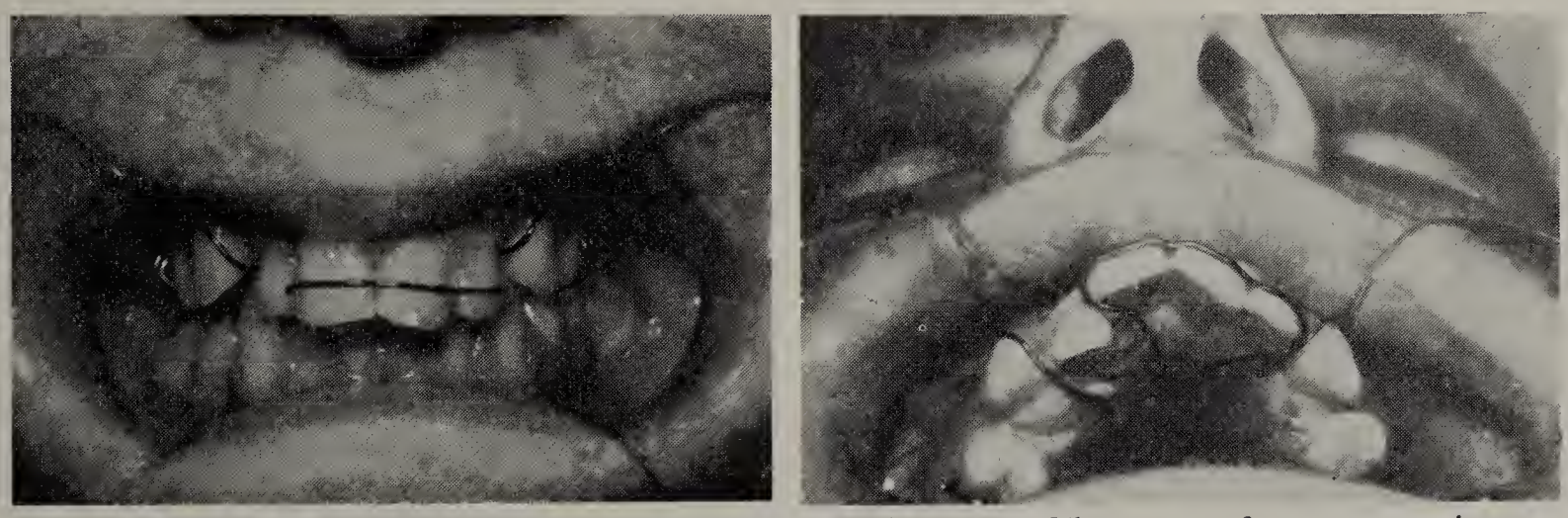


Fig. 11.—The fitted wire adapted to control |2 but permit 2| to space. The extent of spontaneous improvement of 2| can be seen.



Fig. 12.—The universal clasp used on 3|3 while the upper incisors are being moved palatally gives good retention even when extra-oral support is used.

A correctly placed and well-fitted short labial wire may, by splinting the labial segment against the acrylic base-plate, help to limit tipping of the incisors. The extent of this reinforcement in practice is questionable and it would be unwise to depend on it.

A more important aim in appliance design should be to provide good retention which will withstand any displacing forces to which the appliance may be subject. The lateral incisors may be held or allowed to space as the case requires.

The control of anchorage is a necessary consideration in appliance design but it cannot be bought on the cheap and if anchorage is at a premium it should be reinforced with extra-oral traction. Extra-oral traction is easy to fit, cheap to provide, well-tolerated and, above all, effective.

When an appliance is required we have the opportunity, instead of accepting an 'off the peg' model, to design a tool specifically suited to the task in hand. Full advantage should be taken of such a chance and the provision of well-planned anterior retention can play an important part in this.

Acknowledgement

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THE PROBLEM OF REPLACEMENT OF THE UPPER LATERAL INCISOR IN THE YOUNG PATIENT

I. C. BENINGTON,* B.D.S., F.D.S. R.C.S.

Senior Registrar, Department of Prosthetics, Eastman Dental Hospital, London

THE absence of an individual tooth or a pair of teeth is comparatively frequent. Dolder (1937), in an examination of 10,000 schoolchildren aged 6 to 15 years in the school clinic at Berne, recorded congenital absence of teeth in 340 children (3·4 per cent). Of these, 1 tooth was missing in 44 per cent, 2 teeth were missing in 30 per cent, and 3–11 teeth were missing in 20 per cent. Of the individual teeth missing, only 5·3 per cent were mandibular second premolars, 25·3 per cent maxillary second premolars, and 12·3 per cent maxillary second incisors. The third molars were not recorded on account of age. Brekhus, Oliver, and Montelius (1944) have reported that missing teeth occur in the following order of frequency: maxillary second incisors, second premolars, and third molars, whilst any other tooth may occasionally be absent.

It is apparent from these references that the maxillary second incisor or lateral incisor is occasionally missing from the dentition, and the problem of treating such patients usually falls to the hands of the orthodontist in the first place. It may be that realinement of the teeth provides a satisfactory result, but where indicated the orthodontist realines the teeth so that a space of suitable dimensions is created between the central incisor and the canine tooth, with a view to prosthetic replacement. At a later date the possibility of replacing the prosthesis with a bridge may be considered.

The problem of replacing the upper lateral incisors often arises when the patient is undergoing orthodontic treatment and is wearing an orthodontic applicance which incorporates the missing lateral incisors on it. The lateral incisor, being a slender tooth, is fixed to the orthodontic appliance by a narrow isthmus of acrylic, which is easily fractured and is time consuming to replace, and, when the orthodontic treatment has been completed, the problem of replacing the lateral incisors is inherited by the prosthetist. The present paper is concerned with this problem. It is important that a good liaison exists between the orthodontic and prosthetic departments so that the patients in question are seen jointly prior to the completion of the orthodontic treatment. Hence, an ideal clinical situation is achieved in order that the completed treatment is in the best interests of all concerned.

A considerable number of these young patients have been referred to prosthetic departments following orthodontic treatment for a more permanent prothesis which will function as a replacement for the missing teeth and, if necessary, as a retainer. At this stage they are usually aged 13–15 years, when the upper permanent canine has erupted (*Fig.* 1A).

In the treatment plan the following considerations are worth mentioning:—

1. The patients are usually at school and time is therefore important to them.
2. They are at the age when their appearance is becoming increasingly vital, i.e., the aesthetic value of the replacement is a prime factor.
3. At this age the oral hygiene is often found to be neglected and, of course, this can constitute a great problem, as the patient has probably already been wearing an orthodontic appliance for some years and is going to have to wear a prosthetic appliance for the next few years.

It is essential to take impressions for study models and a chilled wax register, so that the models may be accurately articulated and surveyed prior to designing the denture.

One usually finds on examination of the records that, being a young patient, the clinical crowns are short and therefore the survey line is near to or on the gingival margin, thus creating the obvious difficulty with retention. Examination of the posterior articulation will indicate whether access to the buccal surfaces of the teeth can be gained, and it is the position of the survey lines and the dimensions of the interproximal spaces when the teeth are together which determine the type of clasps that may be used to retain the appliance. The relationship of the incisors may be such that the proximity of the lower incisors to the upper ridge provides little space for the base

*Present address: Prosthetic Department, Glasgow Dental Hospital and School.

Presented at the Country Meeting held on 23 April, 1971.

of the prosthesis. When these difficulties are encountered with a child's dentition one is often hesitant to create the necessary space interproximally and incisally by enamel grinding because of the large pulps. As the arch form is often intact with the exception of one or both of the lateral incisors the clasping axis must therefore be remote from the teeth being replaced so that the denture is aesthetically acceptable.

Where the survey lines on the posterior teeth are suitable for orthodox cobalt-chromium clasping the problems of design are minimal and are illustrated in the following case.

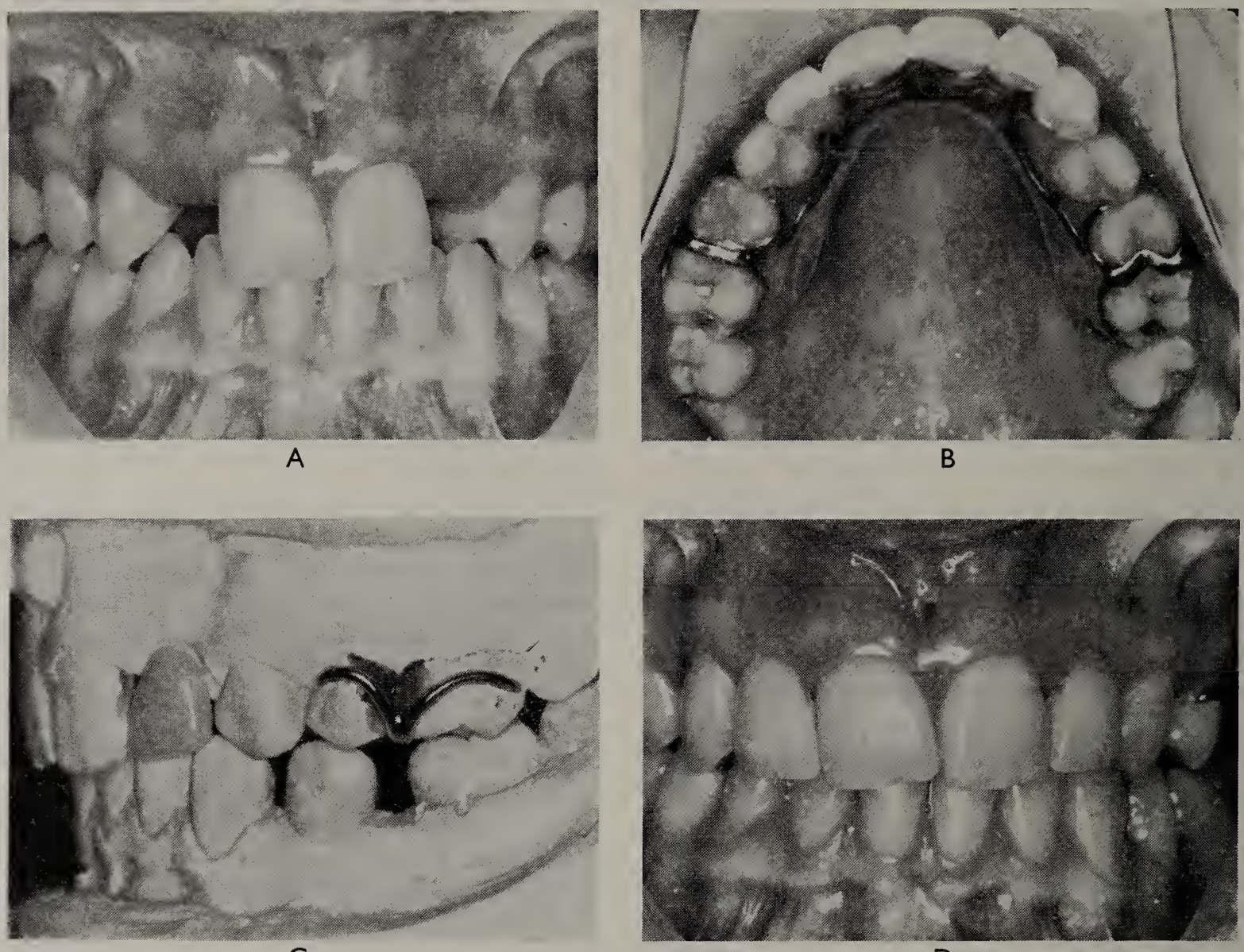


Fig. 1.—A, Child with missing $\underline{2|23}$. B, Palatal view of denture. C, Clasp design of the left side. D, Denture in position.

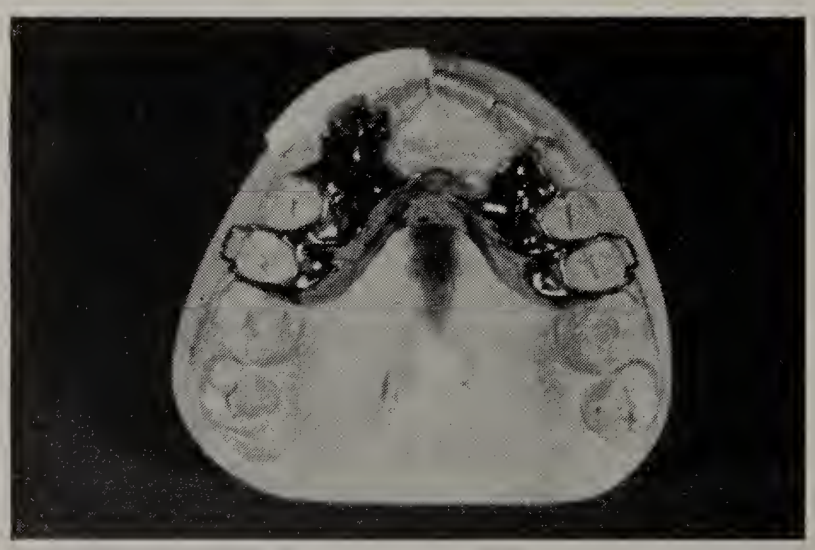


Fig. 2.—Casting with Adams Crib on model.

Case 1

The upper lateral incisors and upper left canine teeth were missing and the patient had completed her orthodontic treatment (*Fig.* 1A). The denture base was a one-piece casting in cobalt-chromium with the clasping axis involving $\underline{65|56}$ (*Fig.* 1B). The skeletal design reduced the gingival involvement and being tooth-borne the denture was less liable to traumatize the palatal tissues. The clasp design was facilitated on the left side by a missing $\overline{|5}$ (*Fig.* 1C), and on the right side where the articulation was good a slight adjustment of the opposing tooth allowed full occlusal contact. The aesthetic value of having a remote clasping axis is seen in the anterior view of the finished prothesis in situ (*Fig.* 1D).

Where we have an accumulation of the problems already mentioned and survey lines do not offer enough undercut to permit the use of cobalt-chromium clasps Adams cribs have been found to be of great value. They provide satisfactory retention where undercuts are minimal and the denture can be designed as shown on the model

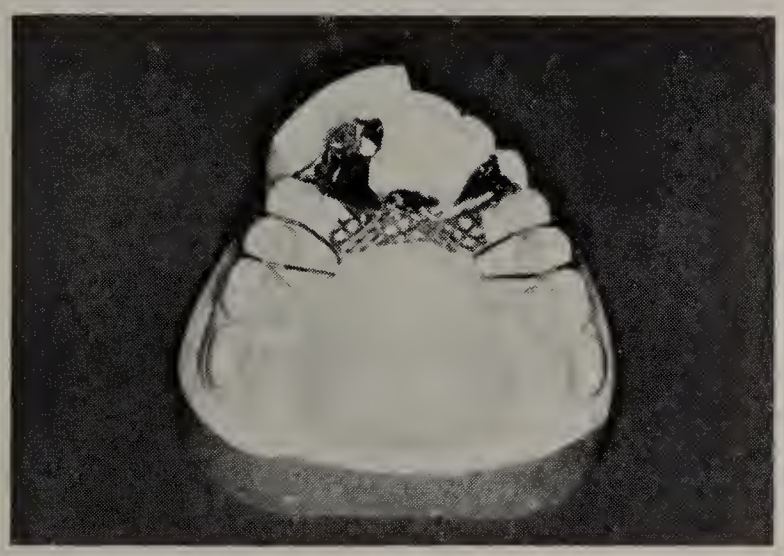
(*Fig.* 2). Unfortunately it is difficult to unite a stainless-steel crib to a cobalt-chromium casting but this can be overcome to a great extent if Wiptam (nickel-chrome) wire is used to construct



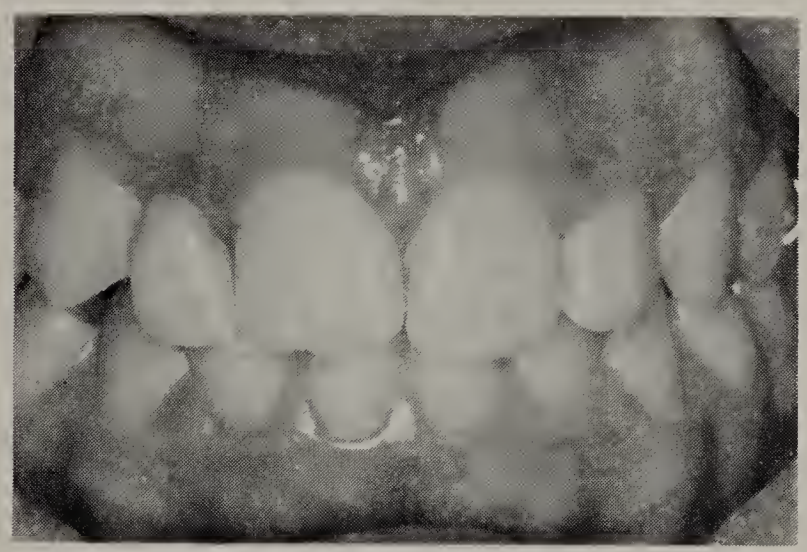
A



B



C



D

Fig. 3.—A, Child with missing $\underline{2|}$ and close bite. B, Trial denture with plaster index. C, Components of denture on model. D, Anterior view of denture in situ. E, Palatal view of denture.

the crib, as it solders more readily to cobalt-chromium. It has been found, however, that the Wiptam cribs are less efficient than those constructed in stainless steel, creating the problem of more frequent adjustments. Also, it was noted that patients wearing this type of appliance had to return to the hospital with cribs fractured at the junction with the casting and these proved difficult and time consuming to repair, and the patients were regretfully deprived of their appliance for some time.

Having struggled with these problems for some time a design was formulated which overcomes them simply. For a case such as the one shown in *Fig.* 3A a small wax palate is constructed and the correct tooth position is achieved at the chairside. A plaster index is taken to ensure that the tooth can be replaced in the identical position on the refractory model so that the wax pattern may be related correctly to it (*Fig.* 3B). A small cobalt-chromium framework is cast which has a posterior border in the form of a retentive lattice. Adams cribs are constructed with their retentive arms



E

related to the posterior edge of the metal lattice (*Fig.* 3C). It is then a simple matter to wax up the posterior section incorporating the cribs in it, position the missing teeth (using the index), and finish the denture in heat-cured acrylic resin. A denture incorporating the design is illustrated in and anterior and mirror view in *Fig.* 3D and E. Several patients have been wearing this type of replacement for approximately 2 years without

suffering any denture fractures. This design was formulated in response to a request from the orthodontic department to provide semipermanent partial dentures following orthodontic treatment. It is intended for use in patients between the years of approximately 12 and 20 or up to the age when a fixed bridge may be supplied if indicated. It has been found satisfactory in use and has the following advantages:—

1. The denture is aesthetically pleasing with no metal showing near the front of the mouth.
2. It is easily and cheaply constructed.
3. The cobalt-chromium portion provides strength to prevent fracture of the isolated teeth on the denture.
4. The retention is good in cases where the undercut areas are small.
5. The appliance is quickly and easily repaired if the Adams cribs have become fractured or detached from the acrylic portion.

Acknowledgements

I am grateful to Mr. S. G. McCallin for providing me with the opportunity of reading this paper and to the Orthodontic Department, Eastman Dental Hospital, for permission to treat their patients.

My thanks are also due to the Photographic Department of the Eastman Dental Hospital.

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Dolder, E. (1937), *Dent. Rec.*, **57**, 142.

REPORTS OF MEETINGS

ORDINARY MEETING, 12 October

An Ordinary Meeting of the Society was held at Manson House, 26 Portland Place, London, W.1., on Monday, 12 October, 1970, at 6.30 p.m. with Professor B. C. Leighton, President in the Chair.

The President said it was with great regret that he had to announce the death of Mr. S. V. Newton, a long-time member of the Society who became a life member, and in fact was one of the first life members to be elected. He was also a member of the British Dental Association and played a large part in administering the Benevolent Fund of the Association. The Society had benefited in having him as its Auditor for many years and owed him a great debt of gratitude.

Members stood in silence for a few moments as a mark of respect to the memory of the late Mr. Newton.

Apologies for Absence

The Secretary read the apologies for absence.

Minutes

The Minutes of the last Ordinary Meeting were read, and were signed as a correct record.

Candidates for Election

The following were elected to Corresponding Membership:—

Mr. M. J. Costello, M.D.Sc. (U. Sydney), B.D.Sc. (U. Queensland), F.A.C.D.S., Suite 45, Civic Arcade, 48–50 George Street, Parramatta, N.S.W. 2150, Australia.

Mr. Sia Tuan Ping, B.D.S. (U. Singapore), D.Orth. R.C.S. (Eng.), Orthodontic Unit, Government Dental Clinic, Jalan Gambut, Kuantan, Panang, Malaysia.

The President welcomed visitors to the meeting and encouraged them to take part in the discussion which he felt might follow the Presidential Address on the present occasion as some of the points raised might be considered contentious, and visitors and members should have an opportunity to hit back!

The President then delivered his Address entitled: *The Value of Prophecy in Orthodontics.*

Professor T. D. Foster opened the discussion. A lively general discussion followed in which Messrs. K. E. Pringle, D. Robertson-Ritchie, and J. Muir, and Dr. J. R. E. Mills participated after which Mr. J. Rose proposed the vote of thanks. The vote of thanks was carried by acclamation following which the meeting was terminated.

REGIONAL MEETING, 23, 24 October

A Regional Meeting of the Society was held in Aberdeen Royal Infirmary on Friday 23 and Saturday 24 October, 1970, with the President, Professor B. C. Leighton, in the Chair.

Professor Alexander MacGregor, Dean of the Medical School, Aberdeen University, welcomed the President and the Society to Aberdeen.

The President thanked Professor MacGregor for his welcome, for the use of lecture theatres, demonstration rooms and the refectory in the University buildings, and for the help given to Mr. Roberts in organizing the meeting. He also thanked Dr. Michie, Group Medical Superintendent of the Aberdeen Royal Infirmary Group of Hospitals for the use of their lecture theatres and for facilities made available to the Society. The President then thanked the Board of Management and Dr. Sexton, Group Medical Superintendent, Aberdeen Special Hospitals, for providing lunch for members and visitors on Friday.

Minutes

The Minutes of the Ordinary Meeting of the Society held at Manson House, 26 Portland Place, London, W.1., on Monday 12 October, 1970, were confirmed and signed by the President. A list of apologies for absence was taken as read.

Introductions to the President

Dr. D. A. Lawrie was introduced to the President and signed the Obligation Book.

Presidential Address

The President then delivered his address entitled: *The Value of Prophecy in Orthodontics.*

The President then invited members to discuss his paper. Mr. I. Clow, Lt.-Col. W. Lervy, and Messrs. S. Haynes, J. Wilkie, H. Pogrel, G. H Roberts, and D. A. Dixon all contributed to the discussion that ensued.

The President thanked those who had taken part in the discussion and then invited Mr. P. H. Morse to read his paper entitled: *Resorption of Anterior Teeth following Orthodontic Treatment.*

The President opened the discussion in which Messrs. J. H. Gardiner, J. G. Houston, G. H. Roberts, and A. Cockburn also took part.

The President proposed a vote of thanks to Mr. Morse and all those who had taken part in the discussion and then announced a break for lunch.

After lunch the President introduced Dr. W. Russell Logan and invited him to read his paper entitled: '*The Evolution of Functional Appliances*'.

The discussion was opened by the President and subsequently Messrs. G. H. Roberts, H. J. Gardiner, and P. I. Townend also took part.

The President proposed a vote of thanks to Dr. Russell Logan and those who had taken part in the discussion and then introduced Mr. D. A. Dixon and invited him to read his paper entitled: '*The Fixed Appliance in Orthodontic Practice Past and Present*'.

Mr. P. H. Morse, Mr. J. H. Gardiner, Lt.-Cmdr. Drake, and Messrs. A. Cockburn, S. Haynes, and A. R. H. Woods took part in the discussion which followed.

The President proposed a vote of thanks to Mr. Dixon and to those who had taken part in the discussion and announced that the table demonstrations would follow a break for tea.

The President asked members to arrange themselves in groups around the demonstrations and to move to the next demonstration when a bell was rung at 15-minute intervals. The President proposed a vote of thanks to Messrs. G. H. Roberts and J. McEwan, Dr. W. Russell Logan, and Mr. R. B. Erskine in advance for their demonstrations.

On Saturday morning the President welcomed Members and visitors to the meeting and then introduced Messrs. L. A. Usiskin and W. G. Webb and invited them to read their paper entitled: '*A Comprehensive Treatment Procedure for the Severe Class II, Division* 1 *Malocclusion*'.

The discussion on the paper was opened by the President and Messrs. J. H. Gardiner, G. C. Dickson, A. R. H. Woods, D. A. Dixon, and M. S. E. Gould also took part.

The President proposed a vote of thanks to Messrs. Usiskin and Webb and to those who had taken part in the discussion and then announced a break for coffee.

After Coffee the President introduced Mr. P. B. Clark and invited him to read his paper entitled: '*Variations on the Standard Operations for Mandibular-maxillary Disproportion*'. Mr. Clark thanked the President for his introduction and said he would confine his talk to consideration of: '*Surgery of the Prognathic Mandible*'.

Following the paper the President invited questions but regretted that, in view of the lateness of the hour, it would not be possible for members to make comment on Mr. Clark's paper.

Following questions by Mr. G. C. Dickson and Lt.-Comdr. Drake to which Mr. Clark and Mr. G. H. Roberts replied the President proposed a vote of thanks to Mr. Clark which was passed with applause.

The President commented on the development of Regional Meetings and of the decentralization of Society activities and proposed a vote of thanks to Mr. G. H. Roberts and his helpers, Mrs. E. Mason and Mr. A. A. M. MacDonald, for their efforts in the preparation for arrangements of a most successful meeting; this was passed with applause.

ORDINARY MEETING, 9 November

An Ordinary Meeting of the Society was held at Manson House, 26 Portland Place, London, W.1., on Monday, 9 November, 1970, at 6.30 p.m., with Professor B. C. Leighton, President, in the Chair.

Minutes

The Minutes of the last Ordinary Meeting were read, and were signed as a correct record.

Apology for Absence

The Secretary reported an apology for absence from Dr. J. D. Atherton.

The President welcomed any visitors who might be present and invited them to take part in the discussion should they desire to do so.

He then introduced Mr. D. G. Huggins from Chester, who showed a short film entitled: '*Orthodontic Tooth Movement using a Multiband Technique*'.

There was a short discussion in which Mr. D. W. Williams asked a question after which the President introduced Professor Foster who read a paper prepared with Mr. Walpole Day entitled: '*An Investigation into the Prevalence of Molar Crossbite and some Associated Conditions*'.

Professor Walther opened the discussion following which there was a general discussion in which Messrs. E. K. Breakspear, S. Gould, and R. Marx participated. The meeting closed after a vote of thanks to the Authors.

ORDINARY MEETING, 14 December

An Ordinary Meeting of the Society was held at 26 Portland Place, London, W.1., on Monday 14 December, 1970 at 6.30 p.m., with Professor B. C. Leighton, President, in the Chair.

The President said it was with some regret that he had to announce the death of Professor M. A. Rushton. He had been a past-President and an Honorary Member of the Society; he had joined in 1931 and had become President in 1948. This was a unique event in the history of the Society because he had been following his own father, William Rushton, who had held the office of President in 1911. His international reputation had been based upon important contributions not only to orthodontics but also to the science of dental surgery and dental practice. In addition to his publications, Martin Rushton had made many significant contributions in discussing the work of others. The Society had lost more than an honoured member; he had been truly a scientist in the broadest sense of the word.

The PRESIDENT said he had also to announce the death of Professor James Scott. He had been a member of the Society, but had resigned, yet they still, as orthodontists, owed him an enormous debt. His contribution to their thinking and their knowledge of the growth and development had probably been more than that of anyone of his generation.

Members stood in silence for a few moments in respect to their memory.

Minutes

The SECRETARY read the Minutes of the Ordinary Meeting of the Society held on Monday, 9 November, 1970, which were confirmed and signed as a true record.

Apologies for Absence

The SECRETARY read the apologies for absence.

New Members

The PRESIDENT welcomed and introduced to the meeting Mr. John Mew.

The PRESIDENT welcomed all visitors and asked them to take part as they wished in any discussion following the papers.

He then introduced Mr. A. M. Cookson, Consultant, of Sutton Coldfield, and called on him to present his paper entitled: '*Space Closure following Loss of First Premolars*'.

Following a lively discussion in which the President, Mr. J. Hooper, Mr. J. S. Rose, Dr. J. Jeffreys, Mr. M. S. E. Gould, and Mr. L. A. Usiskin participated, the President thanked Mr. Cookson and introduced Professor W. A. S. Alldritt who gave a paper entitled '*Gingivitis and Imbrication*'. An enjoyable discussion followed opened by Mr. G. C. Dickson, and followed by Professor G. S. Winter, Mr. C. D. Parker, Mr. H. E. Wilson, and Mr. A. C. Campbell, after which the meeting was closed with a vote of thanks.

ORDINARY MEETING, 11 January

AN ORDINARY MEETING of the Society was held at Manson House, 26 Portland Place, London, W.1. on Monday, 11 January, 1971 at 6.30 p.m., with the President, Professor B. C. Leighton, in the Chair.

The SECRETARY read the Minutes of the Ordinary Meeting held on Monday, 14 December, 1970, which were confirmed and signed as a correct record.

Candidates for Election

The SECRETARY read the list of candidates for election:

Ordinary Membership

Mr. P. S. Burdekin, L.D.S. (U. Leeds), 25 Blossom Street, York.

Miss J. R. Dowsett, B.D.S. (U. Lond), D.Orth. R.C.S.(Eng.), 5 Lullarook Close, Norheads Lane, Biggin Hill, Kent.

Mr. W. Bryan Jones, B.D.S. (U. Birm.), F.D.S. R.C.S.(Edin.), L.D.S. R.C.S.(Eng.), 62 Buryfield Road, Solihull, Warwickshire.

Mr. R. G. Kaplan, B.D.S. (U. Witwatersrand), D.Orth. R.C.S.(Eng.), c/o London House, Mecklenburgh Square, London, W.C.1.

Miss E. M. Scutt, B.D.S. (U. Lond.), L.D.S. R.C.S.(Eng.), 6 The Avenue, West Wickham, Kent.

Mr. D. Orme-Smith, B.D.S. (U. Lond.), L.D.S. R.C.S.(Eng.), Lion Hull, Tadworth Street, Tadworth, Surrey.

Corresponding Membership

Dr. Milan Markovic, Ph.D., B.D.S., D.Orth. (U. Belgrade), Belgrade, Ustanička 129.

These were duly elected.

The PRESIDENT welcomed any visitors present and invited them to take part in any discussion which might follow the papers they were to hear.

The PRESIDENT introduced the authors of the first paper, Mr. J. P. Coen and Dr. T. H. M. Wynne. Mr. J. P. Coen presented the paper entitled: '*Orthodontic Problems associated with a Family affected by an Osteo-Dystrophy*'.

The President opened the paper to general discussion in which Mr. R. T. Broadway, Mr. H. Leech, and Mr. G. C. Dickson participated.

The President then introduced Mr. G. Steel who read a short paper entitled: '*Class II Division 2 Incisor Relationship: Can it be avoided?*'

The President, Mr. C. D. Parker, Mr. P. H. Morse, and Dr. J. D. Atherton participated in the discussion which followed after which the President introduced Mr. L. H. Russell who read a short paper entitled: '*Some Cases of Congenitally Missing Incisors*', after which Dr. J. D. Atherton asked a question.

The last speaker Mr. P. H. Morse was then introduced by the President, and read a short paper entitled: '*A severe Class II Division 1 Malocclusion*'. Following the discussion the President proposed a vote of thanks to the speakers which was carried with acclaim.

ORDINARY MEETING 8 February

AN ORDINARY MEETING was held on Monday, 8 February, 1971 at 6.30 p.m. at Manson House, 26 Portland Place, London. The President, Professor B. C. Leighton, was in the Chair.

Minutes

The SECRETARY read the Minutes of the last Meeting, which were confirmed, and signed as a correct record.

Apologies for Absence

The SECRETARY read the apologies for absence.

Candidates for Election

The SECRETARY read the list of candidates for election:

Ordinary Membership

Mr. T. G. Bennett, B.D.S.(U. Durh.), F.D.S., D.Orth. R.C.S.(Eng.), 3 Barton Close, Harpenden, Herts.

Mr. A. Stewart Chapman, B.D.S.(U. Lond.), L.D.S., D.Orth. R.C.S.(Eng.), Coniston, 22 Old Woking Road, West Byfleet, Surrey.

Mr. I. Clow, B.D.S.(U. St. And.), D.Orth. R.C.S.(Eng.), 5 Harestane Crescent, Dundee DD3 0LQ.

Mrs. J. F. C. Tulloch, B.D.S.(U. Lond.), F.D.S., D.Orth. R.C.S.(Eng.), 31 St. Peters Street, Islington, London, N.1.

Corresponding Membership

Dr. S. Pasikov, D.D.S.(U. Michigan), M.S. (U. Loyola), 380 Washington, Glencoe, Illinois, 60022, U.S.A.

These were duly elected.

The PRESIDENT welcomed any visitors present and invited them to take part in any discussion which might follow the papers they were to hear.

The PRESIDENT introduced Mr. D. Munns, and invited him to read his paper entitled: '*An Analysis of Removable Appliance Breakages*'.

The President opened the discussion and afterwards Mr. C. D. Stephens, Mr. J. J. Crabb, Mr. E. K. Breakspear, Mr. R. T. Broadway, and Mr. J. Selwyn Barnet spoke from the floor.

Chapman Prize Essay, 1970

The PRESIDENT: It now gives me very great pleasure to call on Mr. D. D. Di Biase, who is going to read his winning Chapman Prize Essay, entitled: '*The Effects of Variations in Tooth Morphology and Position on Eruption*'.

Mr. P. H. Burk opened the discussion after which Dr. B. Brown, Dr. J. R. E. Mills, Professor G. B. Winter spoke from the floor.

After the discussion the President presented Mr. Di Biase with the Certificate in Honour of his Essay. (Applause.)

The President then proposed a vote of thanks to the speakers which was carried with acclaim.

ORDINARY MEETING, 8 March

AN ORDINARY MEETING of the Society was held at Manson House, 26 Portland Place, London, W.1. on Monday, 8 March, 1971. The President, Professor B. C. Leighton, was in the Chair.

Minutes

The SECRETARY read the Minutes of the Ordinary Meeting held on Monday, 8 February, 1971, which were confirmed and signed as a correct record.

Apologies for Absence

The SECRETARY read the apologies for absence.

Introductions to the President

Three introductions were made.

Candidates for Election

The SECRETARY read the list of candidates for election:

Ordinary Membership

Mr. B. D. Collin, B.D.S.(U. Dunelm), F.D.S., D.Orth. R.C.S.(Eng.), 46 Vaughan Lodge, Fair Acres, Hayesford Park, Bromley, Kent.

Mr. J. D. Crooks, B.D.S.(U. Lond.), F.D.S., R.C.P.S.(Glasg.), D.Orth. R.C.S.(Eng.), 60 The Hall, Foxes Dale, Blackheath, London, S.E.3.

These were duly elected.

Announcements

The PRESIDENT said he had one sad announcement to make, the death of Mr. G. H. Russell, who had been a benefactor in that he had given the lectern now in use, and which unfortunately was a sort of memorial to him. He had died just recently from a heart attack, and the Society very much mourned his loss. He had done a lot for Orthodontics in arranging for the import of apparatus and devices to which they would not otherwise have had easy access. They owed him quite a debt and Members would be very sorry to hear of his loss.

The President then introduced Mr. J. J. Crabb who read a paper by himself and Mr. N. J. Wilson entitled: '*The Relation Between Orthodontic Spring Force and Space Closure*'.

The President opened the discussion after the paper. Mr. L. D. Stephens, Mr. A. B. Hewitt, and Mr. D. Seel spoke from the floor.

The President thanked Mr. Crabb and then introduced Mr. W. J. B. Houston who read a paper prepared with Professor G. L. Howe and Mr. P. T. Burgess entitled: '*Some Orthodontic and Surgical Observations on Lateral Trepanation of Mandibular Third Molars*'.

A long and lively discussion followed in which the following speakers took part, Messrs. M. A. Kettle, E. S. Broadway, K. Isaacson, H. E. Wilson, C. P. Adams, C. D. Parker, J. Cook, J. R. Pettman, C. Bowdler Henry, and Cradock Henry took part.

The President thanked the speakers and proposed a vote of thanks which was carried with applause.

REGIONAL MEETING, 30 March

A REGIONAL MEETING of the Society was held jointly with the Midland Orthodontic Society in the Birmingham Medical Institute, 36 Harbourne Road, Birmingham, at 5.30 p.m. on Tuesday, 30th March. 1971.

The PRESIDENT welcomed members and visitors from far and near and said how pleased he was to hold a meeting in Birmingham. He congratulated Mr. Munns and the Council of the Midland Orthodontic Society for their perseverance in holding the meeting inspite of the great difficulties created by the postal strike.

Minutes

The Minutes of the Ordinary Meeting held at Manson House on 8 March 1971 were taken as read and the PRESIDENT was authorized to sign them.

The President introduced Mr. J. P. Moss and invited him to read his paper entitled: '*The Unerupted Upper Canine*'.

The discussion was opened by the President and subsequently Messrs. N. Holland, J. Gardiner M. Gould, J. Crabb, V. Iyer, and W. Rook also took part.

The President proposed a vote of thanks to Mr. Moss and to all who had contributed to the discussion. This was passed with applause.

The President thanked Mr. Munns and all those who had helped with the arrangements for the most successful meeting.

COUNTRY MEETING, 22 April

THE THIRTEENTH COUNTRY MEETING of the Society was held in Ranmoor House, University of Sheffield, Shore Lane, Sheffield 16, on Thursday, Friday, and Saturday, 22, 23, and 24 April, 1971. The President Professor B. C. Leighton was in the Chair and 125 Members and Visitors attended the Meeting.

The PRESIDENT welcomed members and visitors to the meeting.

The list of apologies for absence was taken as read.

Minutes

The Minutes of the Ordinary Meeting of the Society held jointly with the Midland Orthodontic Society in the Birmingham Medical Institute, Birmingham, on Tuesday, 30 March, 1971, were read and confirmed and signed by the President.

After some announcements concerning the meeting arrangements the PRESIDENT introduced Mr. H. G. Lewis of the Cardiff Dental School and invited him to read his paper entitled: '*The Attitude of Patients to the Wearing of a Removable Orthodontic Appliance*'.

Dr. J. Luffingham and Messrs. D. G. Huggins, J. Coyle, S. Haynes, R. Marston, and R. A. Campbell took part in the discussion that followed.

The President proposed a vote of thanks to Mr. Lewis and then introduced Mr. S. Haynes and asked him to read his case report entitled: '*Attempted Treatment of a Large Maxillary Diastema associated with Four Supernumerary Incisor Teeth*'.

Messrs. R. T. Broadway, D. A. Dixon, and C. D. Parker took part in the discussion that followed.

The President proposed a vote of thanks to Mr. Haynes and then invited Dr. W. A. B. Brown to read his paper entitled: '*The Maxilla and Mandibular Resemblance between Parents and Their Children*'.

The President opened the discussion that followed and Mr. M. Kettle, Dr. P. Vig, and Mr. D. Bowden also took part. The President then announced a short break for tea.

After tea Dr. Russell Logan took the Chair and after introducing Messrs. J. J. Crabb and H. J. Wilson invited Mr. Crabb to present their joint paper with Mr. N. G. Gough entitled: '*Use of an Adhesive in Orthodontics*'.

After informing the CHAIRMAN and members of the recent death of Mr. Gough, Mr. Crabb read the paper and Messrs. M. Kettle, C. D. Stephens, and L. H. Russell subsequently took part in the discussion that followed.

The Chairman thanked Mr. Crabb and then invited Mr. G. S. Taylor to read his case report entitled: '*Characteristics of Supernumerary Teeth in the Primary and Permanent Dentitions*'.

The Chairman thanked Mr. Taylor and then invited Mr. C. C. Knowles to read his case report entitled: '*Case Report of a Patient with a Lymphangioma*'.

The Chairman thanked Mr. Knowles for his case report and then invited Mr. D. W. Williams to read his joint research report with Dr. J. A. von Fraunhofer entitled: '*An Interim Report on an Electro-chemical Investigation of some Currently Available Stainless-steel Orthodontic Wires*'. Following a question by Mr. H. G. Lewis, the Chairman proposed a vote of thanks to Mr. Williams and Dr. von Fraunhofer and then declared the afternoon session closed.

ANNUAL GENERAL MEETING, 23 April

THE ANNUAL GENERAL MEETING of the Society was held in Ranmoor House, the University of Sheffield on Friday, 23 April, 1971 at 9.00 a.m. The President, Professor B. C. Leighton, was in the Chair and 48 members signed the attendance book.

Minutes

The Minutes of the Annual General Meeting held in May 1970 were read and confirmed and signed by the President.

Election of Officers

The PRESIDENT announced the Election of Officers for the ensuing year. The only nominations received were those appearing on the Agenda Sheet.

On a motion from the Chair it was declared that the nominees were elected.

Election of Councillors

The PRESIDENT reminded members that there are five Councillors each of whom is now elected for a 3-year term of Office without re-election during that period. There would be no vacancies until Mr. R. T. Broadway and Mr. W. A. B. Brown retire at the end of 1972.

Election of Two Auditors

The PRESIDENT thanked Messrs. P. Burke and A. Walpole Day for their past services as Auditors and, as they had signified their willingness to stand again, proposed from the Chair that they be re-appointed as Auditors for the forthcoming year. This was carried unanimously.

Hon. Treasurer's Report

MR. J. MOSS said that the past year had been a difficult year for the Society owing to the rising costs and increased expenditure. At the end of the year there was a deficit of £108 compared with a profit last year of over £500 .

The chief reasons for the deficit were the major increases in the costs of general printing and stationery, publications, and also postage. This latter item would rise again considerably in this present year. Each bound copy of the transactions was costing the Society 35p more to produce than it did the year before. Accountancy and bank charges had also continued to rise. The Country Meeting was one of the most expensive for some time and the cost of the Regional Meetings to the Society was £65 which was the first time that this latter item has been included on the Balance Sheet.

Despite the fact that this has been an extremely difficult year as far as stocks and shares were concerned it was gratifying to see that the market value of the portfolio had increased by £1175 during the past year.

The Council had looked carefully at the accounts and were investigating means whereby economies could be made in order that the subscription for 1972 could be maintained at its present rate. Unless the Society curtailed some of its expenses considerably in the next year an increase in the subscription for 1973 was almost inevitable.

Finally, Mr. Moss said he would like to record his thanks to the previous treasurer, Mr. J. S. Rose, for his help and guidance, and to the auditors, Mr. Burke and Mr. Walpole Day. Mr. Moss then proposed its reception; this was seconded by Professor D. P. Walther.

The PRESIDENT then invited discussion from the floor.

Mr. K. Breakspear felt that the Society should be prepared to face an increase in expenditure rather than restrict its scientific activities. The President thanked Mr. Breakspear for his comments and moved the adoption of the report which was carried unanimously.

Hon. Secretary's Report

MR. M. S. E. GOULD said once again he had to report a very busy year during which there had been a further increase in both the size and activity of the Society.

The Country Meeting held at Brighton last May was attended by 135 Members and visitors and many others who failed to sign the Attendance Book.

During the year 6 Ordinary Meetings had been held at Manson House where the average attendance was 112.

In addition, there had been 2 Regional Meetings: the first, held in Aberdeen in October last year, had two morning and one afternoon sessions extending over 2 days, and was virtually a second Country Meeting. Seventy-five members and visitors, including almost the entire Scottish Membership were present; many of them also attended the most enjoyable Informal Dinner on the Friday evening. The success of the Meeting was due in no small measure to the enthusiasm and efforts of Mr. G. H. Roberts and his team of helpers to whom he and the Council were much indebted. It seems probable that these Scottish Regional Meetings would become a yearly or, at least, bi-yearly event.

The second Regional Meeting was held in Birmingham in conjunction with the Midland Orthodontic Society. It was attended by no fewer than 105 Members and visitors.

The Council were most grateful to the Council of the Midland Orthodontic Society, and in particular to Mr. Munns, for the splendid arrangements for this most successful Meeting which was threatened by the postal strike.

The Membership of the Society continued its growth by the election of 26 new Ordinary and 7 new Corresponding Members during the year. There had been 7 resignations, mostly due to retirement, and, sadly, the Secretary reported the death of two most respected Members. First, that of Professor Martin Rushton, an Honorary Member who was President in 1948, and whose father, William Rushton, was also President in 1911; a unique distinction in the Society's history. The other loss was that of Mr. S. B. Newton who was a Life Member.

The Secretary then reported on the activities of the Council. He said that, as he reported last year, a Sub-Committee was established to review the structure and organization of the Society and how best it could evolve to meet future needs. This Sub-Committee had recently submitted a report to Council which was under active consideration and debate and it seemed probable that some conclusions and decisions would be made during the forthcoming session.

The Council had also been active in other fields and had established Sub-Committees to examine the Society's financial structure and it's Publication policy. A Sub-Committee had also been established to consider making recommendations on ' The Role of Orthodontics in Dental Education '.

There was also a Sub-Committee, still in existence, to continue to advise the Council, should the necessity arise, on the controversial matter of ' Vocational Registration and Specialist Lists '.

The Secretary pointed out that these activities are in addition to the normal routine involved in Administering the Society. Thus the demands made on Council Members, all of whom are busy men, were considerable, and one could not but speculate just how long it would be possible for Honorary Officers to continue to Administer the Society especially if, as some members advocate, there should be a widening of the Society's interests and activities.

The Secretary again expressed his thanks to Miss Ritchie, the Assistant Secretary, who should be more properly designated the Membership Secretary, for her assistance and unfailing support, and to his fellow Officers for their help and counsel.

The Secretary proposed the reception of his report which was seconded by Mr. Gardiner. Professor Robertson congratulated the Council on the progress made in reorganization and looked forward to hearing further details of the Society reorganization. The PRESIDENT then moved the adoption of the Report which was adopted unanimously.

Hon. Editor's Report

DR. J. D. ATHERTON said that the past year had been a very busy year as far as his commitments had been concerned. For the past 10 years there had been an almost logarithmic increase in the amount of material presented to the Society and this year had been no exception. More papers had been presented to the Society than ever before. It has been his policy that members should hear as much as possible provided that the usual high standard was maintained. The continued policy of a short paper followed by a longer one at the London meetings had, he hoped, been a popular one. In addition further new papers had been presented at meetings outside the environs of London in Scotland and the Midlands and next year again there would be at least two meetings outside London.

This increase in the number of papers had raised new problems. The Society's papers were published first in the *Dental Practitioner* and then in the TRANSACTIONS. According to a long-standing arrangement, John Wright & Sons, who publish the *Dental Practitioner*, allowed the B.S.S.O. up to 16 pages of each issue. Whereas in the past it had been possible to get all the papers into 1 year's issue of the *Dental Practitioner* it was now becoming increasingly difficult to get the larger volume into this Journal. A Publications Sub-Committee had been appointed to consider future policy with regard to publication. Meanwhile, however, we had the problem of squeezing into the *Dental Practitioner* as much material as possible. One means of increasing the number of pages available for publication would be to miss out the discussion. It was with great regret and a great deal of anguish that he felt this step to be necessary. However, he personally felt very strongly that all members presenting a paper before the Society should have an equal chance of publication and that the Society should in its turn have as much good material presented to it as possible.

Dr. Atherton proposed the reception of his report and it was seconded by Mr. B. B. J. Lovius.

Messrs. C. P. Briggs and E. K. Breakspear greatly regretted the cessation of publication of the discussions following papers and hoped that the Council would soon be able to resume their publications. Mr. J. J. Crabb suggested that discussions should be published separately in the form of a news sheet and circulated to members subsequently. Professor Walther asked if consideration could be given to limiting the publication of discussion to the openers remarks and the subsequent reply by the speaker. Dr. Mills pointed out that the Society was the only one, to his knowledge, that still carried on the practice of publishing discussions and observed that members must balance the loss of recorded discussion against the more spontaneous discussion which might follow if it was not recorded.

The Editor in reply reiterated what he had said in his report concerning the difficulties of publishing the discussions and said that another factor was the extremely high cost of recording and transcribing discussions.

The PRESIDENT then moved the adoption of the editor's report, which was carried unanimously.

Hon. Curator's Report

MR. R. D. HOWARD said that it had been a matter of concern to successive Curators of the Society's Museum that deficiencies existed in the Society's Collection with regard to orthodontic instruments and apparatus.

Since repeated requests to the membership had failed to produce any material, an approach was made to all the Dental Companies by his predecessor with the possibility of reproducing illustrations of instruments from old catalogues. Discussions have now reached a fruitful stage and although it was hoped to produce some of the results of these negotiations in time for this meeting, this had not proved possible but it was hoped to show the results of this co-operation at the next Country Meeting of the Society.

Meanwhile perhaps the request could be repeated. Should any member find that he or she has any old orthodontic instruments or apparatus in their possession and surplus to their requirements, the Society's Museum would be pleased to receive these.

Mr. Howard proposed the reception of his report which was seconded by Mr. A. C. Campbell. The report was adopted on a motion from the Chair.

Hon. Librarian's Report

MR. A. C. CAMPBELL said that the library continued to be housed with that of the British Dental Association at 64 Wimpole Street, London, W.1. Members were reminded that if they were not members of the B.D.A. they could consult or borrow the Society's books, but not those of the B.D.A.

The Society had added to its collection some back numbers of '*The Journal of the Begg Society*', and copies of '*The Orthodontist*' were being bound.

There was a continuing limited demand for copies of early volumes of the TRANSACTIONS, and he would be glad to hear of any copies available. Of the more recent issues, those for 1960, 1961, and 1962 would be appreciated.

The Librarian had previously mentioned the receipt of a set of TRANSACTIONS from Dr. Clinch. It was interesting to note that the early volumes were those issued to Dr. George Northcroft during his lifetime, and so had a particular historical value for the Society.

In general this had been a fairly quiet year for your Librarian, largely due to the efforts of Mrs. Oates to whom he expressed his thanks.

Mr. Campbell moved the reception of his report and Mr. Rose seconded it. The PRESIDENT then moved the adoption of the Librarian's report and this was carried unanimously.

Any Other Business

Mr. E. J. R. Bird suggested that simplification of the method of electing members at Ordinary Meetings would save time, the PRESIDENT thanked Mr. Bird and said he would refer this matter to the Council for their consideration.

There being no further business the President declared the Annual General Meeting closed and gave permission for the admission of guests.

COUNTRY MEETING, 23 April

ON FRIDAY MORNING, following the Annual General Meeting, the PRESIDENT, after reminding members of Professor Ballard's many contributions to Orthodontics, proposed from the Chair that he be elected an Honorary Member of the Society. This was received with applause.

Candidates for Election

The following candidates for Ordinary Membership were elected *en bloc* by show of hands: Mr. J. C. Bennett, Mr. T. H. Brigham, Mr. L. C. Challis, and Mr. G. F. Holmes.

The PRESIDENT then introduced Professor S. L. Horowitz and invited him to read the 25th Northcroft Memorial Lecture entitled: '*The Challenge of Facial Deformity*'.

Following the lecture the President presented Professor Horowitz with a Commemorative Scroll and proposed a vote of thanks to him which was passed with applause.

After a break for coffee the President introduced Mr. R. D. Howard and invited him to read his paper entitled: '*The Impacted Maxillary Canine: Positional Variations associated with Incisor Resorption*'.

After the discussion in which Messrs. P. M. Benzies, M. A. Kettle, G. Wreakes, and C. D. Parker took part the President proposed a vote of thanks to Mr. Howard.

After lunch Professor D. P. Walther took the Chair and after introducing Mr. I. C. Bennington invited him to read his short paper entitled: '*The Problems of the Replacement of* $\underline{2|2}$ *in the Young Patient*.'

The Chairman opened the discussion that followed in which Messrs. L. H. Russell, N. Upson, and D. A. Dixon also took part.

After thanking Mr. Bennington the President introduced Mr. A. Hudson and invited him to read his paper entitled: '*Corticotomy*'.

The Chairman opened the discussion that followed in which Messrs. J. S. Rose, B. Cryer, G. C. Dickson, K. Breakspear, J. D. Muir, D. Dixon, R. Parkhouse, L. H. Russell, and Dr. J. D. Atherton also took part.

The Chairman proposed a vote of thanks to Mr. Hudson and to those who had taken part in the discussion and announced that Table Demonstrations would follow a break for tea.

The President asked members to arrange themselves in groups around the Demonstration Tables and to move on to the next Demonstration when a bell was rung at 10-minute intervals.

The PRESIDENT proposed a vote of thanks to all the Demonstrators in advance.

COUNTRY MEETING, 24 April

ON SATURDAY MORNING the PRESIDENT introduced Dr. N. J. D. Smith and invited him to present his joint film with Dr. F. L. Ingram entitled: '*Routine Orthodontic Radiography*'.

Following the film the President opened the discussion in which Messrs. D. Seel, R. T. Broadway, A. C. Campbell, G. H. Roberts, J. R. E. Mills, and L. H. Russell took part.

The President proposed a vote of thanks to Dr. Smith and the contributors to the discussion and then invited Mr. J. D. Muir to read his paper entitled: '*Anterior Retention in the Removable Appliance*'.

The President and Messrs. D. Seel, J. Gardiner, and A. C. Campbell took part in the discussion that followed. The President then proposed a vote of thanks to Mr. Muir and those who had taken part in the discussion.

The President introduced Mr. G. H. Roberts and invited him to read his paper entitled: '*Attrition: Facts and Fallacies of Primitive Corn Milling*'. Following the paper, during which Mr. Roberts demonstrated the grinding of corn with a Shetland Quern Stone, the President

proposed a vote of thanks which was passed with applause.

Professor B. C. Leighton's Concluding Speech

At this stage of proceedings as the meeting draws slowly to its close, I have to make a few final remarks. It would be ungrateful of me not to express the appreciation that I and the members have for all those who have taken part in preparing for this meeting.

I should like now to turn to the past year. There is no doubt of the social success of this Society. I think last night was perhaps the climax of that. The social life of the Society is of some importance to orthodontics because we are different from most other clinical practitioners in that the treatment we undertake on our patients is prolonged, sometimes taking years rather than months. It often happens, therefore, that patients have to be transferred from one practitioner to another, and it is an essential part of our work that there should be communication between practitioners.

The times that we live in are turbulent and it is inevitable that the Council shall reflect that turbulence.

Our Treasurer has had a very difficult time this year. You have heard his report.

Dr. Atherton, the Editor, has again been working quietly behind the scenes in preparing the discussions and the transaction of the papers and in guiding the selection of papers.

Now I come to the man who has carried the greatest burden of all on his shoulders—Stephen Gould. I cannot express too fervently my admiration of his industry—he carries everything, he does it with good humour and I must confess that as a past Secretary myself, I could not have carried the burden that he does. I thought I was doing pretty well but in fact he does three times the work that I ever did as Secretary.

Finally, you, the ordinary members, are an important part of this Society. Without your efforts, your attendance, and your support, the Society would collapse and I think it is a great credit to you that so many of you have come up here to Sheffield to this meeting after attending fully two regional meetings during the year.

I now have the task of laying down my office and handing over this badge of office to Dick Mills. It gives me particular pleasure to hand this to Dick Mills because I know that it will be in very safe keeping. He is a man who I admire enormously for his good sense and his catholic knowledge of orthodontics.

Mr. Kettle's Vote of Thanks

Mr. President, Ladies, and Gentlemen, it gives me very great pleasure to propose a vote of thanks to Professor Leighton now that his year of office as President to our Society has come to an end. Barry Leighton has worked hard for us in the Society for a long time and has held office in many forms.

When Barry became President, we all knew that he would make a great success of the job; that's his nature, quiet but tenacious and completely dedicated and having enormous reserves of energy. The job carries great responsibility and has become much more onerous with the introduction of the Country meetings and the supplementary meetings this year in Aberdeen and in Birmingham. Our President has served us in other ways, his contribution at our scientific meetings resulting from his long years of research in the developing of occlusion have been of the greatest value to us. He is now in fact the world authority on this subject.

Professor Barry Leighton, from us all thank you, and long may you serve our interests in the Society.

The Speech of Dr. Mills, the New President

The vote of thanks is clearly passed by acclamation. I am very conscious of the honour that has been done me by electing me as your President and my pleasure is slightly tempered by the difficulty I am going to have in succeeding and keeping up the high standard of Professor Leighton. However, both he and his predecessors have told me that all I have got to do is to do as I am told by the Secretary. I have been told to do two things at this meeting. The first is to announce the date for the next two meetings. The next meeting will be on Monday, 12 October, at 6.30 p.m. in the Manson House when I would warn you that I will be giving my Presidential address, and on Saturday, 23 October, there will be a regional meeting in Dundee which I hope as many of you as possible will attend. My only other duty is to declare the meeting closed.

THE BRITISH SOCIETY FOR THE STUDY OF ORTHODONTICS

Balance Sheet and Income and Expenditure Sheet

FOR THE

YEAR ENDED 31 DECEMBER, 1970

COLE, DICKIN & HILLS,
CHARTERED ACCOUNTANTS, AUDITORS
18, Essex Street, Strand, London, W.C.2

THE BRITISH SOCIETY FOR THE STUDY OF ORTHODONTICS

INCOME AND EXPENDITURE ACCOUNT for the Year ended 31st December, 1970

31.12.1969								
£	£		£	s.	d.	£	s.	d.
11		To *Museum Rent*				10	10	0
		,, *Meeting Expenses:—*						
	54	Hire of Hall	54	0	0			
	84	Refreshments	102	5	6			
	148	Reporting	166	10	6			
	24	Lanterns and Films	39	12	6			
	—	Regional Meetings	65	0	7			
	(15)	Country Meeting (Net) ..	201	6	6			
	52	Northcroft Memorial Lecture	52	10	0			
	13	Sundry Items	4	18	6			
360						686	4	1
26		,, *Chapman Prize* (1970)				26	5	0
		,, *Printing*						
	1379	Publications	1871	15	2			
	329	General Printing and Stationery	395	6	6			
	20	Binding of Journals	—	—	—			
1728						2267	1	8
	8	,, *Insurance*	7	0	9			
	117	,, *Library and Journals*	21	4	0			
	205	,, *Postage*	242	16	7			
	200	,, *Secretarial Assistance*	200	0	0			
	26	,, *Honoraria*	25	5	0			
	84	,, *Accountancy*	105	0	0			
	19	,, *Sundry Expenses*	12	8	8			
	16	,, *Depreciation of Furniture and Equipment*	38	6	0			
	4	,, *Repairs*	3	10	0			
	20	,, *Bank Charges*	47	2	6			
699						702	13	6
545		,, *Excess of Income over Expenditure for the Year*				—	—	—
£3369						£3692	14	3

31.12.1969								
£	£		£	s.	d.	£	s.	d.
	2575	By *Members' Subscriptions*	2692	3	0			
	78	Arrears Collected	154	9	3			
2653						2846	12	3
263		,, *Sale of Transactions*				235	9	3
322		,, *Interest Received and Accrued* ..				342	9	11
131		,, *Income Tax Recoverable* ..				160	0	6
		Excess of Expenditure over Income for the Year				108	2	4
£3369						£3692	14	3

THE BRITISH SOCIETY FOR THE STUDY OF ORTHODONTICS

BALANCE SHEET as at 31st December, 1970

31.12.1969 £	£		£ s. d.	£ s. d.
		Accumulated Fund:—		
	6246	Balance at 1st January, 1970 ..	6790 14 9	
	545	Excess of Income over Expenditure for the year	(108 2 4)	
6791				6682 12 5
		Creditors and Reserves:—		
	1350	Publications Printing Reserve ..	3222 15 2	
	212	Sundry Creditors	232 1 10	
	44	Subscriptions in Advance ..	43 7 0	
	21	Petty Cash Accounts	40 3 6	
1627				3537 7 6
		P. H. BURKE, A. J. W. DAY } *Hon. Auditors*		
		J. P. MOSS *Hon. Treasurer*		
£8418				£10,219 19 11

31.12.1969 £	£		£ s. d.	£ s. d.
		Fixed Assets:—		
	35	Furniture and Equipment Balance at 1st January, 1970	43 0 0	
	24	Addition during the year ..	104 6 0	
	59		147 6 0	
	16	*Less:* Depreciation	38 6 0	
43				109 0 0
		Investments at Cost:—		
	751	Baker Perkins Holdings Ltd. 1372 Ordinary 10/– Shares	750 19 8	
	783	Boulton and Paul Ltd. 450 Ordinary 5/– Shares, 759 Non-Voting Ordinary 5/– Shares	782 16 9	
	151	British Insulated Callenders Cables Ltd. £150 7% Debenture Stock 1985/90	151 4 0	
	455	581 10/– Ordinary Shares ..	454 14 7	
	501	Clydesdale Investment Co. 370 Ordinary 5/– Shares	501 9 7	
	502	Coats Patons Ltd. 920 Ordinary 5/– Shares	502 3 6	
	509	Corporation of London £500 5¼% Stock 1976/79	508 10 9	
	745	Fisons Ltd. 279 Ordinary £1 Shares	744 12 0	
	1310	Liverpool Corporation £1516 4¾% Stock 1970/74	1310 5 0	
	478	Royal Insurance Co. Ltd. 200 Ordinary 5/– Shares	478 10 0	
	761	Sun Alliance and London Insurance Ltd. 210 £1 Ordinary Shares ..	760 13 7	
	497	U.S. Debenture Corporation Ltd. 770 Ordinary 5/– Shares ..	497 4 9	
7443				7443 4 2
		(Approximate Market Value at 31.12.1970 £8650 (31.12.1969, £7475))		
		Current Assets		
381		Income Tax recoverable		410 16 2
23		Prepayments and Dividends receivable		19 2 8
		Cash at Bank and in Hand		
	(692)	Westminster Bank Ltd.	17 1 1	
	19	P.O.S.B.	19 13 5	
	1200	Deposit Account	2200 0 0	
	1	In Hand	1 2 5	
528				2237 16 11
£8418				£10,219 19 11

We have prepared the annexed Balance Sheet and Accounts from the books, records and information given to us and we certify them to be in accordance therewith. We have verified the investments and cash at Bank.

18, Essex Street, Strand, London, W.C.2.
1*st March*, 1971

COLE, DICKIN & HILLS
Chartered Accountants

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